micropaleontology

micropaleontology

articles

news reports

ABSTRACT: *The foraminiferal family Orbitolinidae is represented in rocks of early Cretaceous through Eocene age. The genera* Coskinolinoides, Iraqia, Simplorbitolina, Orbitolina, *and* Dictyoconus *are included in the family because of the similarity of their wall structure and general test development. Genera previously assigned to this family which do not have the characteristic wall structure are removed from the family. Each of the genera assigned to the Orbitolinidae is diagnosed, on the basis of topotypes of the type species of each of the genera.*

Revision of the family Orbitolinidae*

RAYMOND C. DOUGLASS

U.S. Geological Survey
Washington, D.C.

INTRODUCTION

During the past few years I have been assembling collections of *Orbitolina* and some related forms from all over the world for a study of the Orbitolinas of North America. Several problems regarding classification came to my attention during this study, and I have pursued a few of them, especially those which bear on the family Orbitolinidae. The results of this study are presented here because they appear to have wide significance with regard to the interpretation, both biologic and stratigraphic, of some of the late Mesozoic and early Cenozoic larger foraminifera.

Perhaps the principal result of the study is the realization that the detailed structure of the test wall is of prime importance in the classification of the foraminifera involved. Previously, forms with distinctly different wall structure had been included in the same family and even assigned to the same genus. A restudy of topotype material of the genera revealed the essential difference between *Lituonella* of Schlumberger and Douvillé and *Coskinolina* of Stache, and the forms called *Coskinolina* by subsequent authors.

One of the vexing problems has been the interpretation of the variability in the number of subdivisions in the marginal zone. Considerable confusion in the classification of genera within the Orbitolinidae has developed through different interpretations of the significance of the subdivisions. Study of large suites of specimens indicates that the number of subdivisions of the marginal zone is not of generic significance, although it may be a specific character.

A phylogeny for the Orbitolinidae which takes into account not only the morphologic stage of development but also the stratigraphic occurrence of the species is proposed. In this scheme the obvious contradictions such as Cretaceous forms evolving from Eocene "ancestors" are eliminated and a more believable pattern is developed.

The ecology and distribution of the Orbitolinidae are discussed to provide a sounder basis for evaluation of samples on which there is little other paleoecologic or stratigraphic control. Data on paleoecology and distribution are necessarily incomplete, but they provide a base for reference that should prove useful for continued work in this field.

Descriptions of the genera assigned to the Orbitolinidae, based on the type species of each of the genera, are provided or are referred to, so that a clear concept of each genus can be used as a starting point for reassignment of the many species now in the published record. Emphasis in the descriptions is given to forms which are represented in the Western Hemisphere, and their distribution in North America is given in more detail than that in other areas. Illustrations of each of the genera as represented by their type species are assembled for easy reference and to illustrate some of the morphologic characters not previously illustrated.

ECOLOGY

The Orbitolinidae probably lived under conditions similar to those in which most present-day larger foraminifera flourish. Larger foraminifera are now most common in tropical and subtropical waters along shallow coastlines. Although temperature of the water is important, and the larger foraminifera develop best in waters of 15°–35° C., the depth of water is also of great significance (Norton, 1930, p. 332).

Lozo (1944, p. 564–66) considered the orbitolines in the Lower Cretaceous of Texas to have been deposited in shallow warm waters of normal salinity. The orbitolines are commonly associated with rudists which Bergquist and Cobban (1957, p. 873) consider to have developed in warm, clear, shallow waters of normal salinity.

The Orbitolinidae are generally found in close association with biohermal or biostromal deposits. Within this general environment they are found in several facies. They are most common in the lime-rich shales and calcarenites of the fore-reef deposits; they are common, but not abundant, in the reef limestones, and they are present, but not common, in the calcareous sandstones marginal to the reefs.

In Texas the Glen Rose limestone, in which the Orbitolinidae are most commonly represented, was deposited in a shallow sea transgressing over a surface of low relief developed on rocks of Jurassic to Precambrian age. The transgression, as might be expected, was not a steady process but entailed many fluctuations. At any one place the water apparently oscillated between total withdrawal and a depth of several fathoms. This fluctuation is indicated not only by the repetition of lithologies but also by the repetition of faunal assemblages. Dinosaur footprints and other animal tracks, as well as rain prints and mud cracks, indicate shallow-water or mud-flat conditions, whereas rudistid reefs and echinoid and orbitoline assemblages suggest deeper waters.

The distribution of sediment types for any particular time in the past is not easily visualized. In some places the outcrop pattern is such that individual strata are exposed over large areas. More commonly only the edges of the beds can be seen. In the area southwest of Austin, Texas, for instance, the upper part of the Glen Rose limestone is exposed in an area of rounded hills with the alternating weak and resistant beds forming stair-step slopes. The uniformity of the individual beds is accentuated, indicating little variability of environment or sediment type for any particular bed over a relatively large area. In contrast, the exposures of the older beds of the Glen Rose limestone in the same area show considerably greater variability. Massive limestones with rudistids are found which are not continuous, but are transitional into discrete limestone beds laterally.

This relationship is especially well displayed farther west in Texas, and especially in Arizona and New Mexico. Near the Arizona–New Mexico border in southeastern Arizona, and also in the "91 hills" area on the Arizona–Mexico border south of Bisbee, bedded limestones pass laterally into massive rudistid limestones and back into bedded limestones within a distance of about 100 yards.

This two-dimensional picture of the sediments of a time is not sufficient for working out the relationships between sediment and local environment without recourse to information from other sources. The similarity between sediment types found in the Cretaceous and those described by Houbolt from the modern Persian Gulf may serve as a clue in the interpretation of the environments of deposition.

Rounded calcarenites are developed in shallow waters (11 fathoms or less) surrounding most of the reefs (Houbolt, 1957, p. 83). Rounding and some sorting is attributed to breaking waves. The coarser fractions of the rounded calcarenites consist of shells of larger organisms, mostly Mollusca.
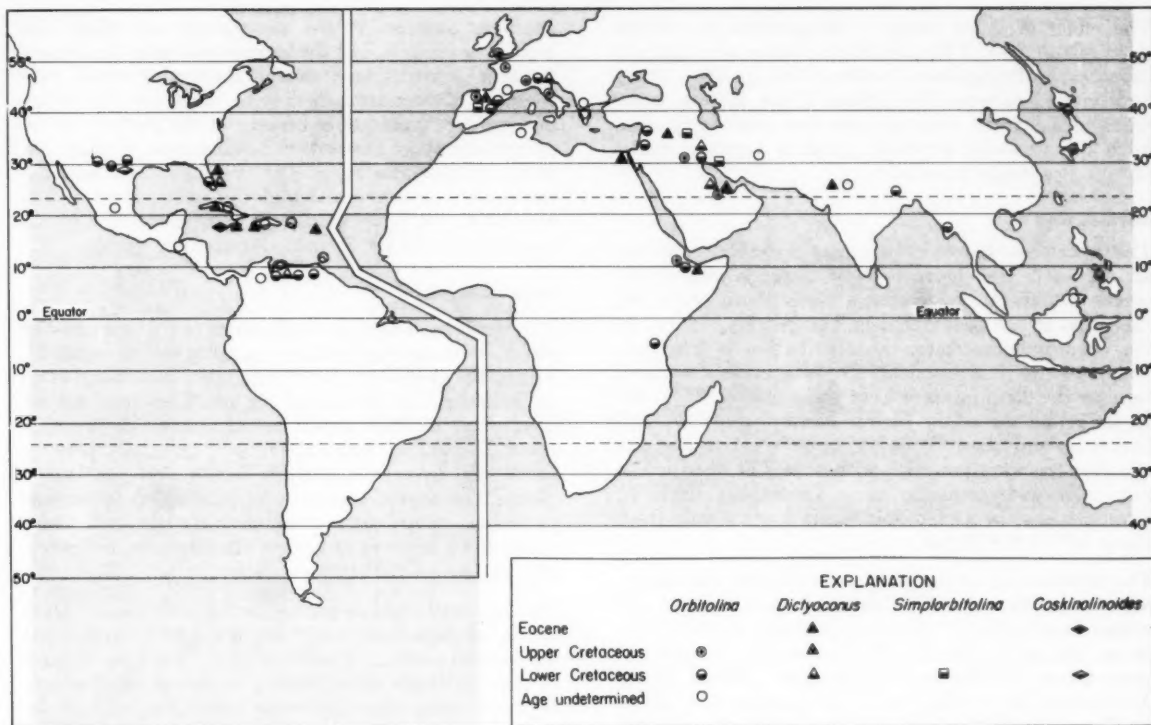
Intergrading with the rounded calcarenites at greater depths are skeletal calcarenites, which contain over 70% skeletal particles and a small amount of particles less than 53 microns in diameter. The coarsest fraction generally consists predominantly of larger foraminifera, and often the larger particles are encrusted with bryozoans and algae. The skeletal calcarenites are found to depths of 22 fathoms and grade upward into the rounded calcarenites. Figures 1–3 on Plate 1 illustrate examples of skeletal calcarenites from the Lower Cretaceous of Texas and Arizona. Figures 7–8 illustrate examples of sediment transitional between skeletal and rounded calcarenite from the Lower Cretaceous of Puerto Rico. *Orbitolina* is abundant in the skeletal calcarenites, and it is common in the rounded calcarenites. Note the algal encrustation on specimens in the rounded calcarenite.

Marly and very marly skeletal calcarenites are accumulating along the rim of the deeper parts of the Persian Gulf area. These sediments consist of skeletal particles and fragments in a fine-grained matrix. Some samples taken from shoal areas have less of the mud, the finer material being small fragments of skeletal particles. Houbolt called these sediments calcilutitic and very calcilutitic calcarenites. Examples of American Lower Cretaceous marly calcarenites and calcilutitic calcarenites with Orbitolinas are illustrated on Plates 1 and 2.

The fact that orbitolines are found in each of these sediment types does not necessarily mean that they lived in each of the environments described. The possibility that they may have lived in a more restricted environment and been transported to others must be considered.

Some sediments, principally the marly calcarenites and calcilutitic calcarenites, contain a large size-range of orbitolines, from specimens in which only the initial chambers are developed, through other stages of development to the adults. In some samples the number of immature specimens approximates the number of adults, in others the immature specimens form only a small proportion of the sample.

EXPLANATION

	Orbitolina	Dictyoconus	Simplorbitolina	Coskinolinoides
Eocene		▲		◆
Upper Cretaceous	⊕	▲		
Lower Cretaceous	◓	△	▱	◈
Age undetermined	○			

TEXT-FIGURE 1

STRATIGRAPHIC AND GEOGRAPHIC DISTRIBUTION OF THE ORBITOLINIDAE

Immature specimens are found but are relatively rare in the skeletal calcarenites, and are seldom found in the rounded calcarenites. Whether, under normal sedimentary and life circumstances, immature tests would accumulate with abandoned mature tests has some bearing on interpretation of distribution patterns. Earl Myers (1942, pp. 337–38) determined that in the samples of *Elphidium* studied, 28% of the specimens died before reaching maturity. A small percentage of these died from parasitism, and the rest had either passed through the digestive tract of a metazoan organism or had died of starvation while buried in the sediments. Very little, if any, physical damage occurred to the tests in passing through the digestive tracts of other organisms.

The presence of adult tests exclusively in a sample may indicate that some sorting has occurred, possibly by waves or currents. This assumption is supported by the facts known about the origin of the rounded calcarenites and skeletal calcarenites in which the adult concentrations most commonly occur. The rounded and skeletal calcarenites were subjected to the greatest amounts of sorting.

Another characteristic of the orbitoline distribution is that some of the beds contain high percentages of orbitoline tests, but in others the tests are scattered through the sediment. Some of these differences can be accounted for by differences in depth of deposition as discussed above. Great differences in numbers of tests per unit volume are known for similar sedimentary types, however. Some explanations for these differences may be considered.

Large variations in the density of Recent populations were noted by Coe (1957, p. 937), who indicated that some littoral populations experience normal minor fluctuations for a number of years and then suddenly increase one hundred-fold or even one thousand-fold over their former numbers. After one or several generations, the population may return to its usual size or may disappear. He cited the example of the "bean clam," *Donax*. In 1950–52, near La Jolla, California, the population exceeded 20,000 individuals per square meter in a zone 2–5 meters wide along about five miles of coast. In the preceding year, the population had averaged less than one clam per square meter. At the end of the two- to three-year normal life span of the clams, the entire population had died out, and extensive search failed to yield a single specimen. In the meantime a younger year class had started on another section of beach two miles away.

The effect of sharp drops in temperature in various parts of the Gulf of Mexico during heavy northers was described by Brongersma-Sanders (1957, p. 949). These have caused catastrophic killings of the shallow-water fauna of the Texas coast and the west coast of Florida. Such killings would probably result in a concentration of tests at a single horizon.

DISTRIBUTION

The reported or known occurrences of the Orbitolinidae are shown in text-figure 1. Most of the known occurrences are from the northern hemisphere, with the exception of one occurrence in Tanganyika, Africa. In the western hemisphere, the distribution is from just under 10° to just over 30° N. lat., and in western Europe, the distribution is from about 30° to 50° N. lat. In the remainder of the eastern hemisphere, the distribution is from about 5° S. lat. to 40° N. lat. The distribution has some variation with time. The distribution was most widespread in early Cretaceous time. In Eocene rocks the Orbitolinidae are known only from about 10° to 40° N. lat.

The distributions of the genera of the Orbitolinidae do not necessarily coincide. *Orbitolina* seems to have the widest distribution. It is restricted in age to the Cretaceous, but geographically its distribution includes all areas where the family is represented. Details of the distribution of *Orbitolina* in North America were given by Douglass (1960). *Dictyoconus* is the next most widely distributed genus. Although it is known from the Cretaceous and Eocene, its geographic distribution is somewhat more restricted than that of *Orbitolina*. *Dictyoconus* has not been reported from the area east of India except on Saipan in the Mariana Islands. *Simplorbitolina* is known only from the Cretaceous of the Near and Middle East. *Coskinolinoides* is known from the Cretaceous of the western hemisphere and the middle Eocene of Jamaica. A summary of the distribution of North American Cretaceous Orbitolinas is shown in text-figure 2.

MORPHOLOGY

A detailed account of the morphology of *Orbitolina* and a glossary of morphologic terms compared with terms used by previous authors was given by Douglass (1960). The following brief review of the morphology is given for convenience of use in understanding the family.

External characters

Specimens of the Orbitolinidae generally have a conical test. The shape varies widely from high-coned forms with pointed apex to broad shield- or disc-like forms. The dorsal surfaces may be plane, slightly convex, or slightly concave, and the base or ventral surface may be convex or concave. Some genera have rather restricted shapes within this range, but there is considerable variation in shape even within some of the species.

Concentric circular depressions normally can be seen on the dorsal surface, marking the position of the chamber sutures. If the depressions are slight the surface is smooth, but the depressions may be deeper, forming a corrugated dorsal surface. Internal subdivisions of the chambers may be visible on the surface of some specimens either because of the partially transparent nature of the test wall or because of slight abrasion of the outer layer. The ventral surface may not show much structure, although the apertural pores may be visible. On some specimens of *Orbitolina* the radial structures of the last-formed chamber are visible.

Internal Characters

The test is built up as a single series of shallow cup-like chambers increasing in diameter more or less regularly. The initial chambers may develop in a spiral form at an angle to the adult portion of the test. The chambers are subdivided in ways which are characteristic for each genus. A distinct marginal zone is generally present, subdivided by vertical and, in some genera, horizontal plates. The central area may be subdivided by vertical partitions, pillars, or a combination of the two. Communication between adjacent chambers is by means of septal or apertural pores.

The test wall consists of two parts. A thin outer layer forms the dorsal surface of the test and extends along the ventral surface of each septum. This layer consists of clear calcite with variable amounts of silica grains. In some specimens the calcite forms the bulk of the outer layer, but in others it is difficult to detect any calcite, and the silica is almost continuous. The inner layer of the wall is composed of granular calcite with an abundance of organic matter. The granules are minute in the outer portions of the test but increase in coarseness toward the center of the test. Toward the center of the test there may also be increasing amounts of detrital material incorporated in the inner layer. In some specimens of *Orbitolina* the amount of detrital material exceeds the cement. The inner wall layer not only coats the inner surfaces of the septa but also is extended inward, where it thickens to form the subdividing partitions and plates of the marginal zone and the partitions or pillars of the central areas.

The subdivisions of the marginal zone are of two kinds: 1) Main partitions which extend across the marginal zone and either extend continuously through the central area or become intermittent as pillars. (2) Plates developed in the outer portion of the marginal zone. There may be only vertical plates developed, or both vertical and horizontal plates may be developed. In some forms several series of these plates are developed. The main partitions divide the peripheral portion of each chamber into chamberlets. The vertical and horizontal plates subdivide the chamberlets into cellules. If more than one series of plates is developed, the outer portion of the marginal zone resembles a keriothecal structure similar to that developed in the Schwagerininae (fusuline foraminifera). Plate 3 illustrates the increasing complexity of the marginal zone in *Dictyoconus* and *Orbitolina*.
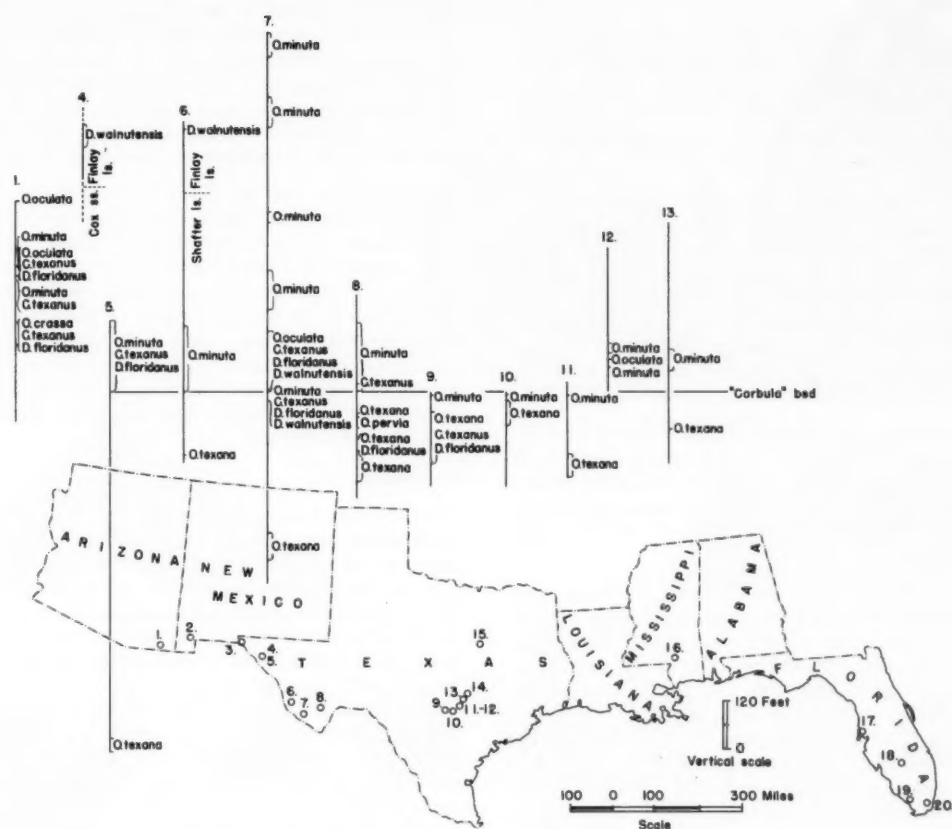
TEXT-FIGURE 2

DISTRIBUTION OF ORBITOLINIDAE IN THE UNITED STATES

1 Mural limestone in the eastern part of the Mule Mountains six miles east of Bisbee, Arizona.
2 Sections of Playas Peak formation, Howells Ridge formation, and Broken Jug limestone with species of *Orbitolina*.
3 Lower Cretaceous limestone in cement quarry on northwest side of El Paso, Texas, with *Dictyoconus walnutensis*.
4 Finlay limestone on Texan Mountain, Sierra Blanca, Hudspeth County, Texas.
5 Devils Ridge and vicinity, Hudspeth County, Texas.
6 Shafter and Finlay limestones at type area of the Shafter limestone just southwest of Shafter, Presidio County, Texas.
7 Glen Rose limestone on Fresno Peak, Presidio County, Texas.
8 Glen Rose limestone in the Hood Springs Quadrangle, Brewster County, Texas.
9 Lower part of Glen Rose limestone along U. S. Highway 281 south of the Guadalupe River, Comal County, Texas.
10 Lower part of the Glen Rose limestone along the Crane's Mill – Fischer's Store road north of Crane's Mill Crossing on the Guadalupe River, Comal County, Texas.
11 Glen Rose limestone along Wimberley – Fischer's Store road west of the Blanco River in Hays County, Texas.
12 Upper part of Glen Rose limestone on the southern slope of Lone Woman Mountain, Hays County, Texas.
13 Glen Rose limestone along the Bee Cave – Hamilton Pool road and on slope of "Shingle" hill, Travis County, Texas.
14 Upper part of Glen Rose limestone and overlying beds on west face of Mt. Barker at Austin, Travis County, Texas.
15 Comanche Peak limestone [1] mile south of Hill Creek bridge on Texas Highway 144 south of Glen Rose, on road to Walnut Springs; rudistid limestone with *Dictyoconus walnutensis*, *D. floridanus*, and *Coskinolinoides texanus*.
16 Limestone lens in Ferry Lake anhydrite at 948–98 feet in Gulf Oil Corp. Andrews well no. 25, Baxterville field no. 12, Lamar Country, Mississippi; rounded calcarenite with *Orbitolina texana*.
17 Lower part of Trinity group, below the "thick anhydrite," at 11,060–70 feet in Coastal Petroleum Co. Wright well no. 1, Pinellas County, Florida, with abundant *Orbitolina texana*.
18 Trinity group in Coastal Petroleum Co. Tiedtke well no. 1, core no. 6, at 11,425 feet, Glades County, Florida, with *Orbitolina texana*.
19 Sunnyland zone in Humble Oil & Refining Co. Gulf Coast Realties well no. C–1, bottom, 11,795–800 feet, Collier County, Florida, with *Dictyoconus floridanus*.
20 Top of Sunnyland zone in McCord Oil Co. Damaco well no. 1, core at 11,753–11,760 feet, Dade County, Florida with *Dictyoconus floridanus* and *Orbitolina texana*.

CLASSIFICATION

The morphologic characters just described have considerable variability. Species have been described which fall within each of the areas of variation, yet they may be grouped according to certain characters into taxa which appear to be reasonable. Five genera can be distinguished with relative assurance:

Orbitolina includes the forms with zigzag main partitions which are continuous at least through the marginal and radial zones. The main partitions are thickened in the upper portion of the chamber in most species. Partitional pores are prominent in some species, tending to interrupt the partitions and form pillar-like structures in the central area. The marginal zone is subdivided by the partitions, and one or more series of vertical and horizontal plates may be developed.

Dictyoconus includes the forms with interseptal pillars in the central area. The central area is usually separated slightly from the marginal zone by a marginal ridge. The marginal zone is subdivided by main partitions and may have one or more series of vertical and horizontal plates.

Simplorbitolina, as here emended, includes the forms that are intermediate in morphology between *Orbitolina* and *Dictyoconus*. The main partitions extend from the marginal zone into the central area of the test in a zigzag manner, as in *Orbitolina*, but the lower portion of each partition is discontinuous, forming pillars, as in *Dictyoconus*. Horizontal sections through the base of a chamber look like *Dictyoconus*, but those through the upper portion of a chamber look like *Orbitolina*. The degree of subdivision of the marginal zone emphasized by Ciry and Rat (1953) in their definition of the genus is not here considered a generic character, in view of the variation in this character shown by other genera of the Orbitolinidae.

Iraqia includes the forms in which the main partitions are reticulate in the central area. The variability of the marginal zone is not fully known, but possibly it is the same as in the other genera of the family.

Coskinolinoides is the simplest form assignable to the Orbitolinidae. Its wall structure and gross morphology are similar to other genera in the family. The marginal zone has only vertical subdivisions, including the main partitions and two series of vertical plates. The main partitions continue into the central area as rather simple plates only slightly thickened toward the top.

EVOLUTIONARY TRENDS

No pronounced trends consistent with the stratigraphic record have been determined. There is an overall tendency toward greater size with time, but the trend is not persistent. For example, in the genus *Orbitolina* the Cenomanian form *O. concava* is the largest species. It is several times as large as most of the Albian species. On the other hand, *O. texana*, in the lower part of the Glen Rose limestone (Albian) of Texas, is larger than most of the species in the overlying beds of the area. The Lower Cretaceous forms of *Dictyoconus* such as *D. floridanus* (which includes the forms described by Maync (1955, p. 106) as *Coskinolina sunnilandensis*) and *D. walnutensis* are small as compared with the Eocene form *D. egyptiensis*, but the relatively small forms *D. floridanus* and *D. walnutensis* are also found in the Eocene.

Complexity of the marginal zone tends to increase through time. The simplest forms have only vertical subdivisions in the marginal zone. Other forms have both vertical and horizontal plates, and some have several series of vertical and horizontal plates. The early forms of *Dictyoconus* such as *D. floridanus* have few marginal subdivisions, with only poorly developed horizontal plates. Most of the later forms have well developed vertical and horizontal plates, but some forms with simply subdivided marginal zones persist in rocks of Eocene age.
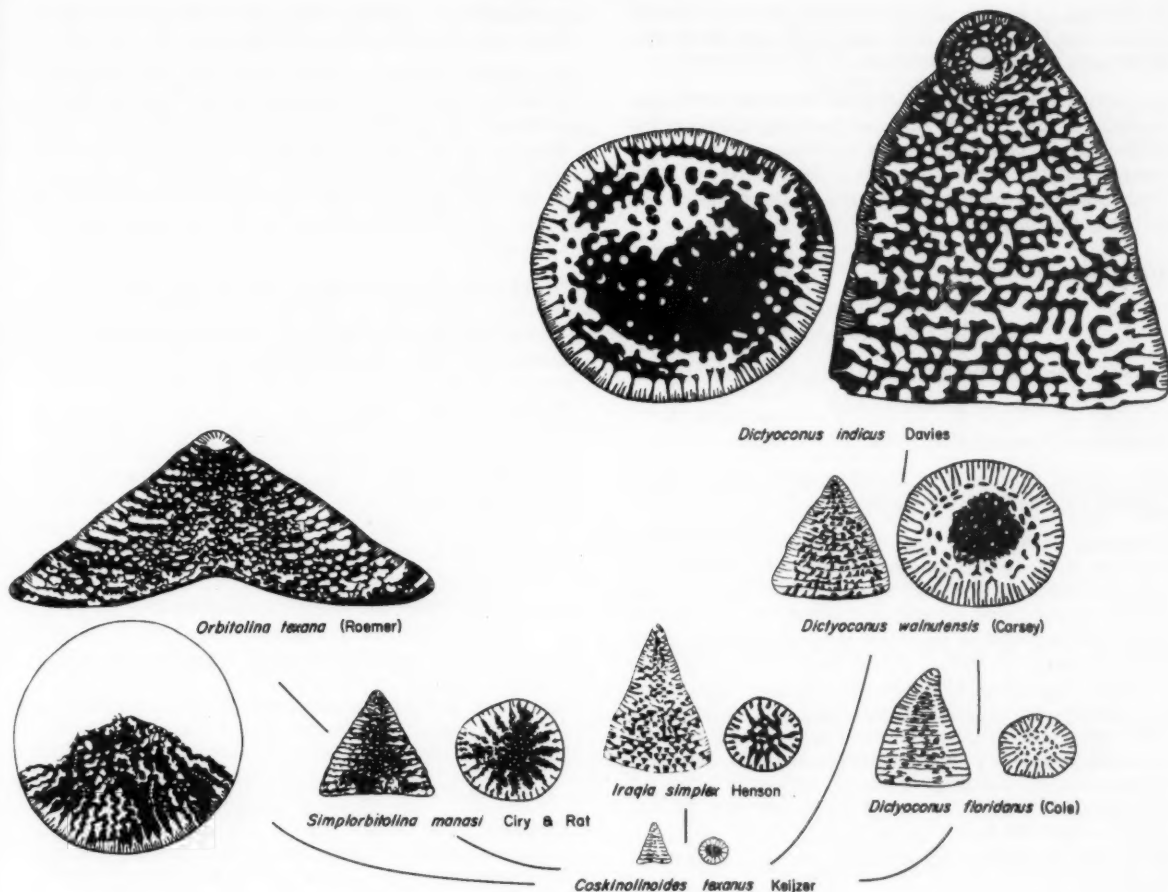
PHYLOGENY

Two primary factors are used for the interpretation of phylogeny, morphologic similarity and time relationships. In early interpretations morphologic criteria were used as the primary control for phylogenetic schemes. Time relationships were neglected or were accorded a minor role. There have been many degrees of refinement in the study and interpretation of morphology. In the early schemes gross morphology was the only character used. Thus, all uniserial forms were grouped and distinguished from the coiled forms. As studies progressed more attention was given to details of growth form, and special emphasis was given to the early chambers of the test. The biogenetic law was applied almost to the exclusion of consideration of the other characters. The nature of the test wall was given some consideration, but for many groups it was not studied in detail.

The last interpretation by Cushman of the forms under consideration (Cushman, 1948, p. 209) included *Dictyoconus* in the Valvulinidae along with *Lituonella*, *Coskinolina*, and *Gunteria*. *Lituonella*, which did not appear until the early Eocene, was given as the ancestor of *Coskinolina*, which was supposed to have evolved into *Dictyoconus*, which is known from the Lower Cretaceous.

Henson (1948, pp. 71–77) discussed the phylogeny of the Orbitolinidae and reviewed previous concepts. His discussion considered both stratigraphic distribution and morphologic variation. Most of his conclusions are applicable, but his concept of the wall structure and his concern over the subdivisions of the marginal zone led to a slightly different interpretation than that here presented. He included *Dictyoconus* in the Orbitolinidae, but he also included *Lituonella* and *Coskinolina* in the same family.

The wall structure of *Lituonella* and *Coskinolina* is the same, but it is different from that found in *Dictyoconus* and other members of the Orbitolinidae. *Lituonella* and

TEXT-FIGURE 3
PHYLOGENY OF THE ORBITOLINIDAE, × 20

Coskinolina have a relatively thick wall with a keriothecal structure which, although indistinct in some specimens, is well developed. The Orbitolinidae have a thin two-layered wall and do not have a keriothecal structure in the same sense as *Lituonella*. The subdivisions of the marginal zone are so numerous in some species of the *Orbitolinidae* as to produce an appearance of a coarse keriotheca (see Plate 3). Possibly the fine keriothecal structure of *Lituonella* is developed by minute subdivision of the marginal area, but this does not appear likely. In any case the phylogeny would not include development of *Dictyoconus* from *Coskinolina,* as suggested by Cushman. The reverse is more possible.

A proposed phylogeny for the Orbitolinidae is shown in text-figure 3. The simplest form in the Orbitolinidae is a form such as *Coskinolinoides texanus,* which has the typical wall structure, simple partitions, and only vertical plates in the marginal zone. From this form there

are variations in several directions. The form *Dictyoconus floridanus* has the pillars characteristic of *Dictyoconus* and a marginal zone with vertical plates and only rudimentary horizontal plates. The form was originally described as *Coskinolina* because of the simplicity of the subdivisions of the marginal zone. The wall structure, however, is not like that of *Coskinolina,* but is typical of the Orbitolinidae. This is one of the simplest forms of *Dictyoconus. Dictyoconus walnutensis* is also a simple form but has the horizontal plates of the marginal zone better developed. Other forms of *Dictyoconus* developed through increase in size and in the complexity of the subdivision of the marginal zone.

The genus *Simplorbitolina,* including the form originally described as *Dictyoconus arabicus* by Henson (1948, p. 35), includes forms intermediate between *Dictyoconus* and *Orbitolina. Simplorbitolina* may have developed from a stock similar to that which gave rise to *D. floridanus. Orbitolina* may have developed only through *Sim-*

plorbitolina, or it may also have developed more directly from a simpler stock. A form such as *O. discoidea delicata* of Henson seems to be primitive.

Iraqia, including the form *Dictyoconus valentinus* of Almela, appears to be another offshoot from the more or less central stock. In this form the partitions are reticulate throughout the central area. It is likely that the form described by Henson as *Dictyoconella* is merely a variant of the genus *Iraqia*.

SYSTEMATIC DESCRIPTIONS

Order FORAMINIFERA
Family ORBITOLINIDAE

Genus **Orbitolina** d'Orbigny, 1850
Plates 1, 2, 4

Orbitolina D'ORBIGNY, 1850, p. 143.

Type species: Orbulites lenticulata Lamarck, 1816 = *Madreporites lenticularis* Blumenbach, 1805.

Diagnosis: Test large (up to 30 mm. in diameter), varying in shape from conical through discoidal to strongly reflexed convexo-concave. Dimorphic, with early microspheric chambers coiled, megalospheric form initiated with a relatively large proloculus; adult in both forms a rectilinear uniserial succession of shallow cup-like chambers. Chambers subdivided into radial passages by zigzag main partitions in the radial zone. The periphery subdivided into marginal chamberlets and cellules by the partitions and vertical and horizontal plates. Communication between adjacent chamber passages by partitional pores. Apertures through the septa at the reentrants of the zigzag main partitions. Test wall incorporating variable amounts of detrital material.

Discussion: Revision of the family Orbitolinidae has clarified the position of several forms of questionable affinity. Among these the following are now assigned to *Orbitolina:*

Orbitolina conulus Douvillé, 1912, was originally assigned to *Orbitolina*. Its type had been used by Douvillé (1904, p. 653) as an example of the morphology of *Orbitolina*. Silvestri (1932a, p. 160) and later Henson (1948, p. 68) suggested that *O. conulus* could not be assigned to *Orbitolina* because of the simplicity of the marginal zone and because there is some reticulation of the main partitions in the central complex. The simplicity of the marginal subdivisions is no longer considered to be a generic character. The basal view of the specimen illustrated by Douvillé (1904, pl. 17) indicates a normal radial zone with radiating main partitions. This form appears to be a typical *Orbitolina*, although if reticulation of the partitions in the central complex is demonstrated in type material, it could be considered to be somewhat intermediate between *Orbitolina* and *Iraqia*.

Orbitolinopsis Silvestri (1932a, p. 160) was proposed for forms similar to *Orbitolina* but with the marginal zone undivided by vertical and horizontal plates. These forms are now assigned to *Orbitolina*.

Orbitolinoides Vaughan (1945, p. 23, pl. 2) was proposed to include some forms which were said to be similar to *Orbitolina* but to differ in not having a marginal zone. Restudy of the type material has revealed a thin but well developed marginal zone in some of the syntypes of the type species, as had been suspected by Henson (1949, p. 176). *Orbitolinoides* is therefore assigned to *Orbitolina*.

Distribution: The distribution of reported occurrences of *Orbitolina* is shown in text-figure 1. *Orbitolina* is found throughout the circumglobal equatorial belt often referred to as Tethyan or Mediterranean. Its reported age range is from Barremian (Lower Cretaceous) to Cenomanian (Upper Cretaceous). In North America it is restricted to rocks of Albian age, although Bonet (1952, p. 181) reported a specimen which he misidentified as *Orbitolina* from the Turonian of Mexico. Details of the distribution of the North American species are given by Douglass (1960, pls. 15–17 and fig. 2) and are here summarized in text-figure 2.

Orbitolina lenticularis (Blumenbach)
Plate 4, figures 1–11

Madreporites lenticularis BLUMENBACH, 1805, no. 80, pl. 80, figs. 1–6.
Orbulites lenticulata LAMARCK, 1816, p. 197. – LAMOUROUX, 1821, p. 45, pl. 72, figs. 13–16.
Orbitolina lenticulata (Lamarck). – D'ORBIGNY, 1850, p. 143, no. 342. – PICTET AND RENEVIER, 1858, p. 166, pl. 23, figs. 3a–f. – DOUGLASS, 1960, p. 29, pl. 1, figs. 1–26.

Diagnosis: Test small (up to 5.2 mm. in diameter), convexo-concave. Embryonic apparatus with a mean diameter of 0.17 mm. and a proloculus with a diameter of 0.09 mm. Marginal zone thin, radial zone poorly developed but with main partitions thick and triangular, coarsely agglutinate.

A description of this species based on three suites of topotype specimens was given by Douglass (1960, p. 29). Nothing of significance can be added to that description at this time.

Genus **Dictyoconus** Blanckenhorn, 1900
Plate 5

Dictyoconus BLANCKENHORN, 1900, p. 434.

Type species: Patellina egyptiensis Chapman, 1900.

Diagnosis: Test variable in size from less than 2 mm. to over 7 mm. in diameter. Shape variable from high coned through low coned, occasionally recurved at the periphery. Initial chambers coiled, adult chambers in a rectilinear uniserial succession. Chambers subdivided in the marginal zone by main partitions, and in most species by vertical and horizontal plates. Central area with interseptal pillars. Apertures through the septa at the base of the pillars. Test wall typical of Orbitolinidae and incorporating variable amounts of detrital material.

Discussion: The following forms are now included in the concept of *Dictyoconus*:

Fallotella Mangin (1954, p. 210) was proposed to include forms similar to *Dictyoconus* but having only vertical subdivisions in the marginal zone. The number of subdivisions in the marginal zone are no longer considered a generic character. The wall, however, is not typical of the Orbitolinidae, and *Fallotella* may not belong in this family (see discussion of "Genera of uncertain affinities" below).

Coskinolina floridana Cole (1941, p. 24) is also assigned to *Dictyoconus*. Its wall structure is like that of the other Orbitolinidae and not like that of true *Coskinolina*. The simplicity of its marginal zone does not distinguish it from other forms of *Dictyoconus*.

Conulites americana of Cushman (1919, p. 43, fig. 3) from the Eocene of St. Bartholomew, Leeward Islands, was used as the type for a new genus *Cushmania* by Silvestri (1925, p. 52). Restudy of the type specimen confirms the current interpretation of this form as *Dictyoconus* (see pl. 3, fig. 2).

Distribution: The reported occurrences of *Dictyoconus* are shown in text-figure 1. *Dictyoconus* has a stratigraphic range from Lower Cretaceous to upper Eocene. It is most common and widespread in the Eocene deposits. Geographically its distribution is similar to that of *Orbitolina*, with the exception of the Far East, where *Dictyoconus* has not been reported.

Dictyoconus egyptiensis (Chapman)
Plate 5, figures 9–12

Patellina egyptiensis CHAPMAN, 1900, p. 11, pl. 2, figs. 1–3.
Dictyoconus egyptiensis (Chapman). – BLANCKENHORN, 1900, p. 419. – SILVESTRI, 1927, pl. 2, fig. 13. – HENSON, 1948, p. 29, pl. 7, figs. 8–9; pl. 12, figs. 6, 9–10, 15.
Dictyoconus coralloides BLANCKENHORN, 1900, p. 435. – HENSON, 1948, p. 32, pl. 12, fig. 7.

Diagnosis: Test small (generally about 3 mm. in diameter and in height of cone), conical with rounded apex. The initial spire is slightly eccentric and protrudes at the side of the apex. Test wall typical of the Orbitolinidae, with little detrital material. Marginal zone subdivided by both vertical and horizontal plates. Central area with well developed pillars and large apertural pores.

Discussion: The forms described as *Dictyoconus egyptiensis* and *Dictyoconus coralloides* have been distinguished by some authors. Henson (1948, pp. 31–33) discussed the relationship between specimens called by these two names and concluded that *Dictyoconus coralloides* "is probably at most a variety of *Dictyoconus aegyptiensis*." The chief difference between the two, as recognized by Henson, is the larger size of the specimens labelled *Dictyoconus coralloides* by Blanckenhorn.

The suites of specimens labelled *D. egyptiensis* and *D. coralloides* in the U. S. National Museum collections

TABLE 1

MEASUREMENTS OF *Dictyoconus egyptiensis* FROM THE MIDDLE EOCENE OF EGYPT		
Name on label	Diameter of base (mm.)	Height of cone (mm.)
D. egyptiensis	2.5	broken
D. egyptiensis	2.5	2.5
D. coralloides	2.7	3.5
D. egyptiensis	3	2.5
D. egyptiensis	3	3
D. coralloides	3	3
D. coralloides	3	3.2
D. coralloides	3	3.2
D. coralloides	3.5	3.5
D. egyptiensis	3	4
D. egyptiensis	5	4
D. coralloides	5.5	4.2

intergrade completely. Table 1 shows the size distribution of the specimens, with an indication of the names appearing on the labels.

Dictyoconus walnutensis (Carsey)
Plate 5, figures 1–8

Orbitolina walnutensis CARSEY, 1926, p. 23, pl. 7, fig. 11a–b; pl. 8, fig. 3.
Coskinolina cookei MOBERG, 1928, p. 166, pl. 3, figs. 1–5, 7–8.
Orbitolina(?) walnutensis Carsey. – VAUGHAN, 1932, pp. 609–610.
Dictyoconus aegyptiensis (Chapman) var. *walnutensis* (Carsey). – SILVESTRI, 1932, p. 377, pl. 1, figs. 10–12; pl. 2, figs. 3–5.
Dictyoconus walnutensis (Carsey). – DAVIES, 1939, p. 775, pl. 1, figs. 4, 6. – COLE, 1942, p. 25, pl. 4, figs. 6–7. – BARKER, 1944, p. 205, pl. 35, figs. 6–8. – LOZO, 1944, pl. 5, figs. 7–11. – MAYNC, 1955, p. 85, pl. 13, figs. 1–7; pl. 14, figs. 1–9.
Dictyoconus cookei (Moberg). – COLE, 1941, p. 26, pl. 3, figs. 11–13; pl. 5, figs. 6–10, 12–13; pl. 6, figs. 1–8; pl. 18, fig. 12. – COLE, 1942, p. 24, pl. 3, fig. 10; pl. 4, fig. 8. – COLE, 1956, p. 214, pl. 25, figs. 6–7.

Diagnosis: Test small (generally less than 2 mm. in largest dimension), conical, with base diameter generally slightly greater than height of cone. Internal structures typical of *Dictyoconus* in both details of the wall and morphology of the chamber subdivisions. Marginal zone subdivided regularly by vertical partitions and plates and somewhat less regularly by horizontal plates, which may be incompletely developed in parts of some specimens.

Description: Excellent descriptions of this species were given by Davies (1939, p. 775) and by Maync (1955, p. 85), and need not be repeated here.

Discussion: Both Maync (1955, p. 90) and Cole (1941, p. 27) noted the similarity of *D. walnutensis* and *D. cookei*. These forms are essentially indistinguishable, even though they occur separated in time.

Distribution: An excellent summary of the distribution of this form was given by Maync (1955, p. 91). In addition

to the stratigraphic range given by Maync, it can now be said that *D. walnutensis* is found ranging up into beds of middle Eocene age. In the United States this species is found in the Lower Cretaceous from Arizona to Florida (see text-figure 2).

Dictyoconus floridanus (Cole)
Plate 5, figures 13–16

Coskinolina floridana COLE, 1941, p. 24, pl. 3, figs. 1–7; pl. 4, figs. 1–9; pl. 5, figs. 1–5, 11; pl. 18, fig. 9. – COLE, 1942, p. 21, pl. 4, figs. 4–5. – COLE, 1945, p. 97, pl. 12, figs. 2–6 (not fig. 8). – COLE AND BERMUDEZ, 1947, p. 6, pl. 1, figs. 1–3, 7, 9. – COLE, 1956, p. 214, pl. 24, figs. 3–5. – COLE, 1958, pp. 222–224, pl. 26, fig. 1.
Coskinolina sunnilandensis MAYNC, 1955, p. 106, pl. 16, figs. 1–2, 5–7; pl. 17, figs. 1–9, 12.

Diagnosis: Test small and conical (maximum dimension approximately 1 mm.), with diameter of base only slightly less than the height of the cone. Structure of the test wall and general internal morphology typical of *Dictyoconus*. Marginal zone subdivided by vertical partitions and plates, but occasional specimens have incipient horizontal plates developed in some of the chambers.

Discussion: Excellent descriptions of this form were given by Cole (1941, p. 24) and by Maync (1955, p. 106). Both authors considered the form assignable to *Coskinolina* because of the incomplete development of horizontal plates in the marginal zone. The wall structure of *D. floridanus* is unlike that of *Coskinolina*, however, and is typical of the structure found in other Orbitolinidae. As shown previously, the degree of subdivision of the marginal zone is not a generic character.

Maync (1955, p. 109) noted the morphologic similarity between the forms described as *Coskinolina floridana* Cole (1941, p. 24), from the middle Eocene, and *Coskinolina sunnilandensis* Maync (1955, p. 106), from the Lower Cretaceous. He found that the only differentiating criterion is the slightly larger size of the Eocene forms. The size range of the forms from the two horizons overlap considerably, and they are here considered to represent the same species.

Distribution: D. floridanus was described from the middle Eocene of Florida. It has since been recognized in the upper Eocene of Jamaica (Cole, 1956, p. 210), and in the Lower Cretaceous of Florida, Louisiana, Texas, New Mexico, Arizona, Mexico, Venezuela, and Switzerland.

Genus Coskinolinoides Keijzer, 1942

Coskinolinoides Keijzer, 1942, p. 1016.

Type species: Coskinolinoides texanus Keijzer, 1942.

Diagnosis: Test small (about 0.5 mm. by 0.5 mm.), acutely conical, with a straight or slightly curved axis. Initial chambers indistinct but reported as forming a

trochoid spiral at a slight angle to the adult portion of the test. Adult chambers in a uniserial rectilinear series. Each adult chamber subdivided by vertical partitions, main partitions extending to the axis, primary and secondary plates extending a short distance toward the axis. Apertural pores limited to the central portion of each septum. Test wall as in other orbitolinids but with little or no detrital material.

Discussion: Coskinolinoides is structurally the least complex form assigned to the Orbitolinidae. Its relations to some of the other members of the family are not altogether clear.

Distribution: Coskinolinoides has been recognized in limited areas of North and South America in rocks of early Cretaceous age, and in the middle Eocene of Jamaica.

Coskinolinoides texanus Keijzer
Plate 6, figures 7–13

Coskinolinoides texanus KEIJZER, 1942, p. 1016, text-figs. b–h. – HENSON, 1949, p. 175. – FRIZZELL, 1954, p. 76, pl. 6, fig. 27. – MAYNC, 1955, p. 89. – MAYNC, 1955, p. 109, pl. 17, figs. 14–15.
Coskinolina adkinsi BARKER, 1944, p. 206, pl. 35, figs. 1–4. – LOZO, 1944, p. 550, pl. 5, figs. 3–6. – STEAD, 1951, p. 592, pl. 2, figs. 16–18.

Diagnosis: Test small (about 0.5 mm. in diameter), conical, with height of cone approximately equal to the diameter of the base. Test wall as in other Orbitolinidae, but with little or no detrital material. Chambers subdivided by main partitions and vertical plates. Subdivisions all simple, not specialized in the form of pillars or zigzag partitions, as in more advanced Orbitolinidae.

Description: Coskinolinoides texanus is one of the smallest forms assigned to the Orbitolinidae. Specimens of adult tests are commonly 0.3 to 0.5 mm. in maximum dimension. The test is commonly acutely conical with a straight or curved axis and a pointed or rounded apex. The dorsal surface generally has concentric depressions at the juncture of the successive chambers, and the wall is thin enough so that the vertical pattern of the partitions and plates can be seen when specimens are moistened. The ventral surface is slightly concave, and small circular apertures are commonly visible in the axial portion.

The nepionic chambers are reported to form a trochoid spire (Keijzer, 1942, p. 1016; Barker, 1944, p. 207). They are generally at a slight angle to the adult portion of the test, forming a curved axis in the early stages. Microspheric and megalospheric generations have not been distinguished in *C. texanus*, although some specimens are more acutely pointed at the apex than others.

The neanic and ephebic chambers are uniserial in a rectilinear series. The chambers are not easily separable into the three zones generally recognized in the Orbito-

linidae. Instead, only two zones, a marginal trough and a central shield, are seen. The marginal trough is subdivided by radial vertical partitions which extend in from the margin toward the central area. The main partitions continue into the central zone, but the primary and secondary plates extend only part of the way. The main partitions are plane, not zigzag, and thicken only slightly in the central zone. The thickening of the main partitions, coupled with the arching of the chamber floor, tends to separate the marginal trough from the central zone.

Apertural pores are developed within the central zone. The septum or chamber floor is thickened around the apertural pores, indicating a tendency toward the development of pillars.

Distribution: C. texanus was originally described from the Walnut clay, of Lower Cretaceous (Fredericksburg) age, west of Austin, Texas. The forms described by Barker as *Coskinolina adkinsi* were from the same horizon but from Mt. Barker, at Austin. Barker (1944, p. 206) recognized this form at several places in central Texas, at the base of the Fredericksburg.

Genus **Simplorbitolina** Ciry and Rat, 1953

Simplorbitolina CIRY AND RAT, 1953, pp. 85–100.
Dictyoconus Blanckenhorn. – HENSON, 1948 (part), p. 35, pl. 1, figs. 5–8; pl. 14, figs. 1–12.

Type species: Simplorbitolina manasi Ciry and Rat, 1953.

Diagnosis: Test small (generally less than 3 mm. in diameter), conical; initial chambers in a short curve at the apex, adult chambers in a uniserial rectilinear series. Marginal zone subdivided by main partitions and one or more series of plates. Radial zone with radiating main partitions which are progressively more broken by partitional pores toward the axis of the test. Lower portion of the partitions often as discrete pillars, merging toward the top of each chamber. Test wall with outer clear layer and inner granular layer.

Discussion: The form described as *Dictyoconus arabicus* Henson (1948, p. 35) has all the essential characters of *Simplorbitolina* and is included in the concept of this genus. Henson recognized that *S. arabica* is an intermediate form between *Orbitolina* and *Dictyoconus.*

Simplorbitolina manasi Ciry and Rat
Plate 6, figures 1–6

Dictyoconus sp., CUVILLIER AND SACAL, 1951 (part), pl. 21, fig. 1.
Simplorbitolina manasi CIRY AND RAT, 1953, p. 85, pl. 1, figs. 1–7.

Diagnosis: Test small (generally less than 1.5 mm. in maximum dimension), conical, with height of cone about equal to diameter of base. Internal structures intermediate between those of *Orbitolina* and those of *Dictyoconus*, the zigzag main partitions typical of *Orbitolina* broken into the discrete pillars of *Dictyoconus*

toward the base of each chamber. Marginal zone subdivided by the main partitions and one or more series of vertical plates. Occasional horizontal plates developed in some chambers.

Description: The test is small (up to 1.5 mm. in maximum diameter) and conical, with a rounded apex. The dorsal surface has indistinct concentric lamellae in well preserved specimens. Abraded specimens commonly display a well developed "brickwork" pattern developed by the septa and the vertical partitions. The initial chambers of microspheric specimens are in a small oblique coil. The adult portion of the test is composed of a rectilinear series of chambers. Megalospheric specimens have a proloculus, a short curving nepionic stage, and a rectilinear adult portion.

The chambers are divided into three general areas, as in *Orbitolina* and *Dictyoconus.* The marginal zone is subdivided by main partitions and vertical plates. Most specimens have one or two series of vertical plates, but there is considerable variability even within one chamber. Occasional horizontal plates are developed in some specimens. The development of the horizontal plates is erratic, as in *Dictyoconus floridanus.*

The radial zone includes most of each chamber. The main partitions develop the zigzag pattern typically developed in *Orbitolina.* They, are triangular in cross section, with the thickening toward the roof of the chamber. Partitional pores are exceptionally well developed and tend to break up the partitions into discrete pillars. The partitions are most completely broken toward the base of each partition and toward the axis of the test. Apertural pores are also common and tend to be aligned along the main partitions. In the central zone, pillar-like structures are well developed in some specimens, but in others the main partitions appear to coalesce. Apertural pores are common. The test wall is typical of the Orbitolinidae, and has fine detrital material incorporated in the granular portion.

Discussion: Topotype material of *S. manasi* was made available by Pierre Rat. Seven free specimens and four thin sections, including hundreds of specimens in limestone matrix, were studied. *S. manasi* and *S. arabica* are the only two species currently assigned to this genus. *S. arabica* differs from *S. manasi* in size, being twice the size of *S. manasi* on the average. *S. arabica* is also more similar to *Dictyoconus* in that the main partitions are more completely broken into pillars than in *S. manasi.* *S. manasi* tends more toward *Orbitolina* than does *S. arabica.*

Distribution: S. manasi was originally described from Navarre, Spain, from beds of uncertain age. The probable age (Ciry and Rat, 1953, pp. 97–98) is Aptian or Albian. These authors also identified a specimen figured by Cuvillier and Sacal (1951, pl. 21, fig. 1) from probably basal Albian beds as belonging to this species. This form has not been reported from the Western Hemisphere.

Genus **Iraqia** Henson, 1948

Iraqia Henson, 1948, p. 69.

Type species: Iraqia simplex Henson, 1948.

Diagnosis: Test small (less than 2 mm. in diameter), conical; initial chambers in a spire, adult chambers in a uniserial rectilinear series. Marginal zone subdivided by main partitions and may have one or more series of vertical and horizontal plates. Central area subdivided by reticulate partitions instead of radiating partitions or pillars.

Discussion: Dictyoconus valentinus Almela, 1946, was proposed for a form from the Cenomanian of Spain. This form has reticulate partitions in the central area and is therefore assigned to *Iraqia*. The similarity was also noted by Henson (1949, p. 175).

Dictyoconella Henson, 1948, was proposed for compressed *Dictyoconus*-like forms from the Upper Cretaceous of Arabia and Iraq. The true relations of this form are difficult to determine, but from the description and illustrations it appears to be most closely related to *Iraqia*.

Genera of uncertain affinities

Several genera formerly considered to be members of the Orbitolinidae do not have the essential characters of the family as now understood. These forms are discussed briefly below, to assist in their assignment to other families.

Fallotella: Proposed by Mangin (1954, p. 210), with *F. alavensis* as the type species. He considered it similar to *Dictyoconus* but differing in the number of subdivisions of the marginal zone. The gross morphology is similar to that of *Dictyoconus* (see pl. 6, figs. 14–19), and it may well be assigned to that genus. The wall structure of topotypes of *F. alavensis* is not identical with that of other Orbitolinidae. As pointed out earlier, the wall of typical orbitolinids consists of two parts: an outer layer which forms the dorsal surface of the test and curves in to form the ventral surface of each septum, and an inner layer covering the inner surface of the primary layer and also extending in to form the partitions and plates of the marginal zone. Two layers cannot be distinguished in the outer wall of *F. alavensis*, and the partitions may be multilayered (see pl. 6, fig. 19). The outer wall is of approximately the same thickness as that of *Simplorbitolina manasi*, but the partitions and plates of *F. alavensis* are at least twice as thick as those of *S. manasi*.

Coskinolina: Originally described by Stache (1875, p. 335) from beds of middle Eocene age, in Istria. The locality from which the material was obtained was carefully recorded, along with the stratigraphic interval and associated fossils. Unfortunately, Stache did not illustrate any specimens. Schubert (1912, pp. 195–208, pl. 10, figs. 1–9) redescribed *Coskinolina* and illustrated some specimens of conical foraminifera from the island of Melada off the Istrian-Dalmatian coast. Two different forms were included in the illustrations by Schubert. His figures 1 and 6 differ from the others and also appear to represent free specimens as opposed to specimens in a limestone matrix.

Through the courtesy of A. R. Loeblich, Jr., then of the U. S. National Museum, I was able to obtain a large sample of limestone from the type locality of *Coskinolina liburnica* as described by Stache. This material is very similar to that illustrated by Schubert in his figures 4–5, 7–8, and 9, and contains abundant specimens meeting the brief description given for *Coskinolina* by Stache. It does not include any specimens resembling those illustrated by Schubert in his figures 1 and 6.

The test wall in these forms is coarsely granular and is perforated by closely spaced transverse pores. The wall is about five times as thick as that found in the Orbitolinidae, and it is not composed of two layers, as in that family (see pl. 6, figs. 20–21).

For comparison I prepared several sections of topotype specimens of *Lituonella roberti* Schlumberger and Douvillé, 1905. These specimens appear to be identical with the material described by Stache, both in gross morphology and in the detailed structure of the test wall.

The following forms cannot be assigned to the Orbitolinidae, but I am uncertain of their proper disposition.

Kilianina: Established by Pfender (1936, p. 123) to accommodate *Kilianina blancheti* Pfender (1936, p. 123, pls. 1–2). The illustrations given by Pfender do not permit determination of the type of wall present. The gross morphology of the internal structures is also obscure from the description and illustrations. Henson (1948, p. 70) included *Kilianina* in the Orbitolinidae, as did Glaessner (1947, p. 98). Neither author discussed the detailed structure of this form. Until authentic material can be studied, the position of *Kilianina* remains uncertain.

Lituonelloides: Proposed by Henson (1948, p. 26, pl. 6, fig. 1, and text-fig. 2a–c) for a compressed conical form from the Maestrichtian of Arabia. It is said to have a well marked marginal zone without subepidermal partitions. The illustrations are not conclusive, but suggest a thick wall such as is found in *Coskinolina*. If this is true, the form can not be assigned to the Orbitolinidae.

Coskinolinopsis: Proposed by Henson (1948, p. 27, pl. 10, figs. 4–5, 7, 13, (?)12) for flabelliform, compressed, somewhat conical specimens from the Triassic or Jurassic of Oman and the Jurassic of Cyprus. The illustrations suggest a form with a thick wall, but the structure is indistinct. The form does not appear to be assignable to the Orbitolinidae.

Howchinia and *Valvulinella: Howchinia* Cushman (1927, p. 42) and *Valvulinella* Schubert, (1907, p. 211) were assigned to the Orbitolinidae by Cushman (1940, p. 193). Neither of these forms has either the gross internal structure or the test wall structure of the Orbitolinidae.

BIBLIOGRAPHY

ALMELA, A.
1946 – *Una nueva especie de "Dictyoconus" del Cenomanense valenciano.* Inst. Geol. Min. España, Notas y Comun., no. 16, pp. 151–156, 1 pl.

BARKER, R. W.
1944 – *Some larger foraminifera from the Lower Cretaceous of Texas.* Jour. Pal., vol. 18, no. 2, pp. 204–209, pl. 35.

BERGQUIST, H. R., AND COBBAN, W. A.
1957 – *Mollusks of the Cretaceous.* Geol. Soc. Amer., Mem., no. 67, vol. 2, pp. 871–884.

BLANCKENHORN, M.
1900 – *Neues zur Geologie und Paläontologie Aegyptens.* Deutsch. Geol. Ges., Zeitschr., vol. 52, pp. 403–479.

BLUMENBACH, J. F.
1805 – *Abbildungen naturhistorischer Gegenstände.* Göttingen (1796–1810), pt. 8, no. 80, 2 pp., pl. 80.

BONET, F.
1952 – *La facies Urgoniana del Cretácico Medio de la región de Tampico.* Asoc. Mex. Geol. Petrol., Bol., vol. 4, nos. 5–6, pp. 153–262, text-figs. 1–50.

BRONGERSMA-SANDERS, M.
1957 – *Mass mortality in the sea.* Geol. Soc. Amer., Mem., no. 67, vol. 1, pp. 941–1010.

CARSEY, D. O.
1926 – *Foraminifera of the Cretaceous of central Texas.* Texas, Univ., Bull. (Bur. Econ. Geol.), no. 2612, pp. 1–56, pls. 1–8.

CHAPMAN, F.
1900 – *On a Patellina-limestone and another foraminiferal limestone from Egypt.* Geol. Mag., new ser., no. 4, vol. 7, pp. 3–17, pl. 2.

CIRY, R., AND RAT, P.
1953 – *Description d'un nouveau genre de foraminifère: Simplorbitolina manasi.* Bull. Sci. Bourgogne, vol. 14 (1952–1953), pp. 85–100, pl. 1, text-figs. 1–5.

COE, W. R.
1957 – *Fluctuations in littoral populations.* Geol. Soc. Amer., Mem., no. 67, vol. 1, pp. 935–940.

COLE, W. S.
1941 – *Stratigraphic and paleontologic studies of wells in Florida.* Florida, Geol. Survey, Bull., no. 19, pp. iii–vi, 1–91, pls. 1–18, 5 text-figs., 1 table.

1942 – *Stratigraphic and paleontologic studies of wells in Florida; no. 2.* Florida, Geol. Survey, Bull., no. 20, pp. iii–vi, 1–89, pls. 1–16, text-figs. 1–4.

1945 – *Stratigraphic and paleontologic studies of wells in Florida; no. 4.* Florida, Geol. Survey, Bull., no. 28, pp. 1–160, pls. 1–22, 9 text-figs., tables 1–17.

1956 – *Jamaican larger foraminifera.* Bull. Amer. Pal., vol. 36, no. 158, pp. 205–233, pls. 24–31, tables 1–6.

1958 – *Larger foraminifera from Carriacou, British West Indies.* Bull. Amer. Pal., vol. 38, no. 171, pp. 219–229, pls. 26–29.

COLE, W. S., AND BERMUDEZ, P. J.
1947 – *Eocene Discocyclinidae and other foraminifera from Cuba.* Bull. Amer. Pal., vol. 31, no. 125, pp. 1–36, pls. 1–7.

CUSHMAN, J. A.
1927 – *An outline of a re-classification of the foraminifera.* Cushman Lab. Foram. Res., Contr., vol. 3, pt. 1, pp. 1–105, pls. 1–20.

1940 – *Foraminifera, their classification and economic use.* Cambridge, Massachusetts: Harvard Univ. Press. 535 pp., 48 pls.

1948 – *Foraminifera, their classification and economic use.* Cambridge, Massachusetts: Harvard Univ. Press. 605 pp., 55 pls., text-figs. 1–9.

CUVILLIER, J., AND SACAL, V.
1951 – *Corrélations stratigraphiques par microfaciès en Aquitaine Occidentale.* Leiden: E. J. Brill, 23 pp., 90 pls., maps.

DAVIES, L. M.
1939 – *An early Dictyoconus, and the genus Orbitolina: their contemporaneity, structural distinction, and respective natural allies.* Roy. Soc. Edinburgh, Trans., vol. 59, pt. 3 (1938–1939), no. 29, pp. 773–790, pls. 1–2, text-figs. 1–6.

DOUGLASS, R. C.
1960 – *The foraminiferal genus Orbitolina in North America.* U. S. Geol. Survey, Prof. Paper, no. 333, pp. 1–52, pls. 1–17, text-figs. 1–32.

DOUVILLÉ, H.
1904 – *Sur la structure des Orbitolines.* Soc. Géol. France, Bull., ser. 4, vol. 4, fasc. 5, pp. 653–660, pl. 17.

FRIZZELL, D. L.
1954 – *Handbook of Cretaceous foraminifera of Texas.* Texas, Univ., Bur. Econ. Geol., Rept. Invest., no. 22, pp. 1–232, pls. 1–21.

GLAESSNER, M. F.
1947 – *Principles of micropalaeontology.* New York: John Wiley and Sons Inc., 296 pp., 14 pls.

HENSON, F. R. S.
1948 – *Larger imperforate foraminifera of south-western Asia.* London: British Museum (Natural History), pp. v–xi, 1–127, pls. 1–16, text-figs. 1–16.

1949 – *Recent publications on larger imperforate foraminifera of the Middle East.* Ann. Mag. Nat. Hist., ser. 12, vol. 2, no. 15, pp. 173–177.

HOUBOLT, J. J. H. C.
1957 – *Surface sediments of the Persian Gulf near the Qatar Peninsula.* The Hague: Mouton, 113 pp., 28 text-figs.

KEIJZER, F.
1942 – *On a new genus of arenaceous foraminifera from the Cretaceous of Texas.* K. Nederl. Akad. Wetensch., Proc., vol. 45, pp. 1016–1017.

LAMARCK, J. B.
1816 – *Histoire naturelle des animaux sans vertèbres.* Paris: Vol. 2, pp. 1–568.

LAMOUROUX, J. V. E.
1821 – *Exposition méthodique des genres de l'ordre des Polypiers.* Paris: pp. 1–115, pls. 1–84.

LOZO, F. E.
1944 – *Biostratigraphic relations of some North Texas Trinity and Fredericksburg (Comanchean) foraminifera.* Amer. Midland Nat., vol. 31, no. 3, pp. 513–582, pls. 1–5, text-figs. 1–22, 1 table.

MANGIN, J. P.
1954 – *Description d'un nouveau genre de foraminifère: Fallotella alavensis.* Bull. Sci. Bourgogne, vol. 14, pp. 209–219, 1 pl.

MAYNC, W.
1955a *Dictyoconus walnutensis (Carsey) in the middle Albian Guacharo limestone of eastern Venezuela.* Cushman Found. Foram. Res., Contr., vol. 6, pt. 3, pp. 85–96, pls. 13–14.

1955b *Coskinolina sunnilandensis, n. sp., a Lower Cretaceous (Urgo-Albian) species.* Cushman Found. Foram. Res., Contr., vol. 6, pt. 3, pp. 105–111, pls. 16–17.

MOBERG, M. W.

1928 – *New species of Coskinolina and Dictyoconus? from Florida.* Florida, Geol. Survey, Ann. Rept., no. 19, pp. 166–170, pls. 3–5.

MYERS, E. H.

1942 – *A quantitative study of the productivity of the foraminifera in the sea.* Amer. Philos. Soc., Proc., vol. 85, no. 4, pp. 325–342, 1 pl.

NORTON, R. D.

1930 – *Ecologic relations of some foraminifera.* California, Univ., Scripps Inst. Oceanogr., Bull., Tech. Ser., vol. 2, no. 9, pp. 331–388, text-figs. 1–3, tables 1–6.

ORBIGNY, A. D'.

1850 – *Prodrome de paléontologie stratigraphique universelle des animaux mollusques et rayonnés faisant suite au cours élémentaire de paléontologie et de géologie stratigraphiques.* Paris: vol. 2, 427 pp.

PFENDER, J.

1936 – *Sur un foraminifère nouveau du Bathonien des montagnes d'Escrains (Hautes-Alpes).* Grenoble, Univ., Fac. Sci., Lab. Géol., vol. 18, pp. 121–130, 2 pls.

PICTET, J. F., AND RENEVIER, E.

1858 – *Description des fossiles du terrain Aptien de la Perte du Rhône, et des environs de Sainte-Croix.* Matériaux Pal. Suisse, ser. 1, no. 1 (1854–1858), pp. 1–184, pls. 1–23.

SCHLUMBERGER, C., AND DOUVILLÉ, H.

1905 – *Sur deux foraminifères éocènes, Dictyoconus egyptiensis Chapman et Lituonella roberti nov. gen. et sp.* Soc. Géol. France, Bull., ser. 4, vol. 5, fasc. 3, pp. 291–304, pl. 9, text-figs. 1–7.

SCHUBERT, R. J.

1907 – *Vorläufige Mitteilung über Foraminiferen und Kalkalgen aus dem dalmatinischen Karbon.* Austria, K. K. Geol. Reichsanst., Verh., vol. 5, pp. 211–214.

1912 – *Über Lituonella und Coskinolina liburnica Stache sowie deren Beziehungen zu den anderen Dictyoconinen.* Austria, Geol. Reichsanst., Jahrb., vol. 62, pp. 195–208, pl. 10.

SILVESTRI, A.

1925 – *Sulla diffusione stratigraphica del genere "Chapmania", Silv. e Prev.* Accad. Pont. Sci. Nuovi Lincei, Mem., ser. 2, vol. 8, pp. 31–60, pl. 1.

1927 – *Fossili esotici nel Paleogene della Brianza.* Soc. Ital. Sci. Nat., Atti, vol. 66, pp. 105–112, pls. 1–6, text-figs. 7–9.

1932a *Foraminiferi del Cretaceo della Somalia.* Paleontogr. Ital., new ser., vol. 32, pp. 143–204, pls. 9–16, text-figs. 1–9.

1932b *Revisione di Orbitoline nordamericane e nuovi località di Chapmanine.* Accad. Pont. Nuovi Lincei, Mem., ser. 2, vol. 16, pp. 371–394, pls. 1–2.

STACHE, G.

1875 – *Neue Beobachtungen in den Schichten der liburnischen Stufe.* Austria, K. K. Geol. Reichsanst., Verh., pp. 334–338.

STEAD, F. L.

1951 – *Foraminifera of the Glen Rose formation (Lower Cretaceous) of central Texas.* Texas Jour. Sci., vol. 3, no. 4, pp. 577–605, 3 pls., text-figs. 1–7.

VAUGHAN, T. W.

1932 – *The foraminiferal genus Orbitolina in Guatemala and Venezuela.* Nat. Acad. Sci., Proc., vol. 18, no. 10 pp. 609–610.

1954 – *American Paleocene and Eocene larger foraminifera.* Geol. Soc. Amer., Mem., no. 9, pt. 1, pp. 1–122, pls. 1–46, text-figs. 1–11, 11 tables.

EXPLANATION OF PLATES

PLATE 1

All figures × 10

1 Skeletal calcarenite with *Orbitolina texana* (Roemer), from the lower part of the Glen Rose limestone in Brewster County, Texas; Coll. f20121, slide 29; U.S.N.M. no. 626479.

2 Skeletal calcarenite with *Orbitolina crassa* Douglass, from the Mural limestone in Cochise County, Arizona; Coll. f20273, slide 1; U.S.N.M. no. 626480.

3 Skeletal calcarenite with *Orbitolina texana* (Roemer), from the lower part of the Glen Rose limestone in Comal County, Texas; Coll. f20103, slide 32; U.S.N.M. no. 626481.

4 Calcilutitic calcarenite with *Orbitolina oculata* Douglass, from the upper part of the Mural limestone in Cochise County, Arizona; Coll. f20250, slide 12; U.S.N.M. no. 626482.

5 Very marly calcarenite with *Orbitolina texana* (Roemer), from the lower part of the Glen Rose limestone in Comal County, Texas; Coll. f20103, slide 40; U.S.N.M. no. 626483.

6 Very marly calcarenite with *Orbitolina texana* (Roemer), from the lower part of the Glen Rose limestone in Comal County, Texas; Coll. f20102, slide 10; U.S.N.M. no. 626484.

7–8 Rounded calcarenite or skeletal calcarenite from Cretaceous limestone from the Comerio Quadrangle, Puerto Rico; Coll. f20386, slides 8 and 2; U.S.N.M. nos. 626485 and 626486.

PLATE 2

All figures × 10

1 Very marly calcarenite with *Orbitolina texana* (Roemer), from the lower part of the Glen Rose limestone in Comal County, Texas; Coll. f20109, slide 12; U.S.N.M. no. 626487.

2 Very marly calcarenite with *Orbitolina minuta* Douglass, from the upper part of the Glen Rose limestone in Brewster County, Texas; Coll. f20130, slide 8; U.S.N.M. no. 626488.

3 Calcilutitic calcarenite with *Orbitolina texana* (Roemer), from the lower part of the Glen Rose limestone, Comal County, Texas; Coll. f20107, slide 5; U.S.N.M. no. 626489.

4–5 Calcilutitic calcarenite or skeletal calcarenite with *Orbitolina minuta* Douglass, from the upper part of the Glen Rose limestone in Hays County, Texas; Coll. f20091, slide 34, and coll. f20090, slide 30; U.S.N.M. nos. 626490 and 626491.

6–7 Calcilutitic calcarenite with *Orbitolina concava* (Lamarck), from the Cenomanian at Ballon, France; Coll. f4862, slide 1; U.S.N.M. no. 626492.

8 Very marly calcarenite with *Orbitolina texana* (Roemer), from the lower part of the Glen Rose limestone in Comal County, Texas; Coll. f20105, slide 18; U.S.N.M. no. 626493.

9 Large rounded fragment of very marly calcarenite in a matrix of very marly calcarenite; both contain *Orbitolina oculata* Douglass; from the upper part of the Glen Rose limestone in Hays County, Texas; Coll. f20092, slide 8; U.S.N.M. no. 626494.

PLATE 3

All figures × 100

1 A portion of the holotype of *Dictyoconus fontabellensis* (Vaughan), originally described as *Cushmania*; Eocene, Fontabella at River Rise, Trelawny, Jamaica; U.S.N.M. no. 626495.

2 A portion of the holotype of *Dictyoconus americanus* (Cushman), originally described as *Conulites*; Eocene, St. Bartholomew, Leeward Islands; U.S.N.M. no. 626496.

3–4 Portions of topotypes of *Dictyoconus egyptiensis* (Chapman), from the Eocene of Egypt; U.S.N.M. nos. 626497 and 626498.

5–6 Portions of axial and basal sections of *Dictyoconus walnutensis* (Carsey), from Mt. Barker at Austin, Texas; the specimens figured are on the same slides as those figured by Barker (1944, pl. 35, figs. 6–8); U.S.N.M. nos. 626499 and 626500.

7–8 Portions of axial and basal sections of *Dictyoconus floridanus* (Cole), from the upper part of the Glen Rose limestone on Fresno Peak in Presidio County, Texas; Coll. f20141, slides 2 and 6; U.S.N.M. nos. 626501 and 626502.

9–10 Portions of axial and tangential sections of *Orbitolina concava* (Lamarck), from the type locality at Ballon, France; Coll. f4862, slides 4 and 1; U.S.N.M. nos. 626505 and 626492.

11 Portion of near-basal section of *Orbitolina texana* (Roemer), from the lower part of the Glen Rose limestone in Comal County, Texas; Coll. f20105, slide 13; U.S.N.M. no. 626502.

12 Portion of an axial section of *Orbitolina texana* (*Roemer*), from the lower part of the Glen Rose limestone in Kendall County, Texas; Coll. f20113, slide A3; U.S.N.M. no. 626504.

13 Portion of a basal section of *Orbitolina minuta* Douglass, from the upper part of the Glen Rose limestone in Hays County, Texas; Coll. f20095, slide 51; U.S.N.M. no. P5463.

14 Portion of an axial section of *Orbitolina minuta* Douglass, from the Bluff Mesa formation in Hudspeth County, Texas; Coll. f20178, slide 6; U.S.N.M. no. P5464.

15–16 Portions of basal and axial sections of *Orbitolina parva* Douglass, from the Playas Peak formation in Grant County, New Mexico; Coll. f20228, slides 4 and 37; U.S.N.M. nos. P5497 and P5495.

PLATE 4

1–11 *Orbitolina lenticularis* (Blumenbach)

Topotypes from Perte du Rhone, Ain, France: 1, near axial section, × 50, slightly oblique but grazing the proloculus, U.S.N.M. no. 626506; 2, portion of axial section of an abraded specimen, × 50, U.S.N.M. no. 626507; 3, portion of basal section of an abraded specimen, × 50, U.S.N.M. no. 626508; 4–5, axial sections, × 10, U.S.N.M. nos. 626509–626510; 6, tangential section of an abraded specimen, × 10, U.S.N.M. no. 626511; 7–9, three of Blumenbach's original illustrations, × ca. 5; 10–11, ventral and dorsal views of two specimens, × 5, U.S.N.M. nos. 626512–626513.

12–13 *Orbitolina concava* (Lamarck)

Topotypes from Ballon, France, portions of axial sections, × 50: 12, megalospheric proloculus with well developed supraembryonic area, U.S.N.M. no. 626505; 13, peripheral portion of the test, with well developed marginal zone and illustrating annular nature of the chambers, U.S.N.M. no. 626505.

14–18 *Orbitolina senni* (Vaughan)

14, portion of specimen in fig. 15, × 30, photographed wet to show fine subdivisions of the marginal zone; 15, specimen illustrated by Vaughan (1945) as fig. 2 on plate 2, × 5, U.S.N.M. no. 626514; 16, specimen illustrated by Vaughan (1945) as fig. 5 on plate 2, × 20, U.S.N.M. no. 626515; 17, broken specimen identified but not illustrated by Vaughan, × 10, Senn collection no. S36, Barbados; 18, portion of the same specimen, × 30, showing subdivisions of the marginal zone, U.S.N.M. no. 626516.

PLATE 5

All figures × 20

1–8 *Dictyoconus walnutensis* (Carsey)

1, 5, subaxial sections, from Mt. Barker at Austin, Texas, U.S.N.M. nos. 626499 and 626500; 3, subaxial section of a topotype from the Walnut clay on the Bull Creek road 3.7 miles west of the bridge west of Austin, Texas, Coll. 1092 of Plummer, U.S.N.M. no. 626517; 2, 4, 7, basal sections of topotype specimens, U.S.N.M. nos. 626518, 626519, and 626520; 6, 8, axial and basal sections of specimens from the Finlay limestone near Sierra Blanca, Texas, U.S.N.M. nos. 626521 and 626522.

9–12 *Dictyoconus egyptiensis* (Chapman)

9, 12, basal sections from the Eocene of Egypt, Sta. 17969, El Mineidra, Ramliya Expedition, U.S.N.M. nos. 626498 and 626524; 10, axial section from the Eocene of Egypt, Sta. 17970, west of Wadi Ramliya, U.S.N.M. no. 626525; 11, tangential section from Sta. 17969, Egypt, U.S.N.M. no. 626523.

13–16 *Dictyoconus floridanus* (Cole)

13–15, specimens from the Sunnyland zone, Humble Oil & Refining Co. Gulf Coast Realties well no. C.1, bottom, 11,795–800 feet, Collier County, Florida, U.S.N.M. nos. 626526, 626527, and 626528; 16, specimen from the top of the Sunnyland zone, McCord Oil Co. Damaco well no. 1, core 23, Dade County, Florida, U.S.N.M. no. 626529.

PLATE 6

1–6 *Simplorbitolina manasi* Ciry and Rat

Topotypes: 1, 2, portions of axial and basal sections, × 100, U.S.N.M. no. 626530; 3, subaxial section of a specimen with unusually large diameter, × 20, U.S.N.M. no. 626530; 4, basal and deep tangential section, × 20, U.S.N.M. no. 626530; 5, basal and random sections, × 20, U.S.N.M. no. 626531; 6, basal section, × 20, U.S.N.M. no. 626532.

7–13 *Coskinolinoides texanus* Keijzer

7, portion of an axial section, × 100, from the Walnut clay on Mt. Barker, Austin, Texas; U.S.N.M. no. 626533; 8, portion of a basal section, × 100, from the same locality, U.S.N.M. no. 626534; 9–10, axial sections of two of Barker's types described as *Coskinolina adkinsi*, × 20, U.S.N.M. no. 103795; 11, basal section of one of Barker's types of *C. adkinsi*, × 20, U.S.N.M. no. 103794; 12–13, axial sections of specimens from the Walnut clay on Mt. Barker, Austin, Texas, × 20, U.S.N.M. no. 626533.

14–19 *Fallotella alavensis* Mangin

Topotypes: 14, basal section, × 20, U.S.N.M. no. 626535; 15, basal section, × 20, U.S.N.M. no. 626536; 16, axial section, × 20, U.S.N.M. no. 626535; 17, subaxial section, × 20, U.S.N.M. no. 626537; 18–19, portions of axial and basal sections, × 100, U.S.N.M. no. 626535.

20–21 *Coskinolina liburnica* Stache

Topotypes: 20, portion of an axial section, × 100, showing porous or fibrous character of the test wall, U.S.N.M. no. 626538; 21, portion of a basal section, × 100, with similar structure visible in the test wall in the right-hand portion of the photograph; compare the structure shown here with that shown in plate 3; U.S.N.M. no. 626539.
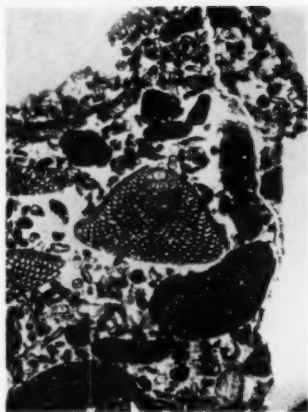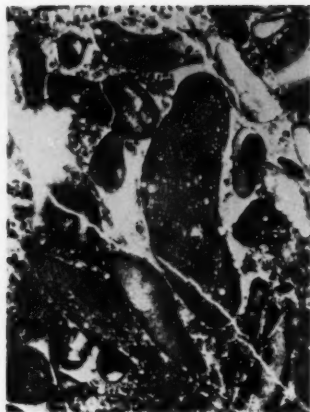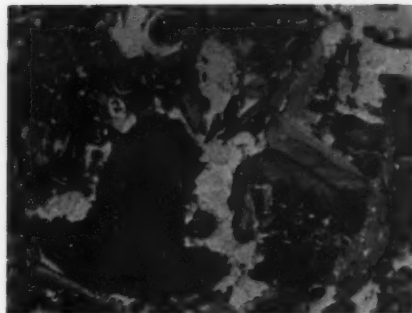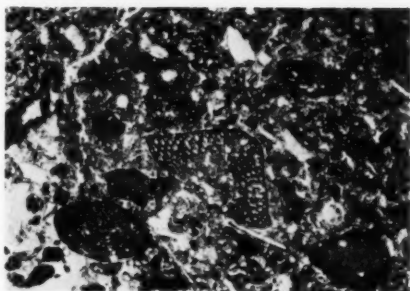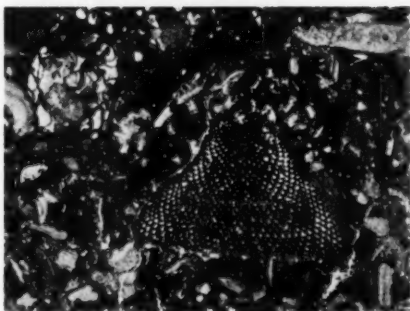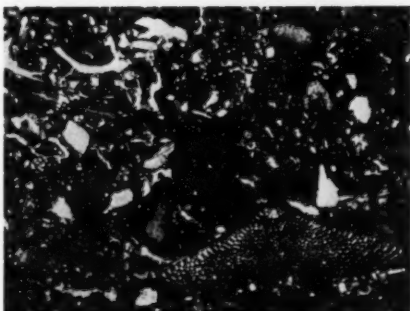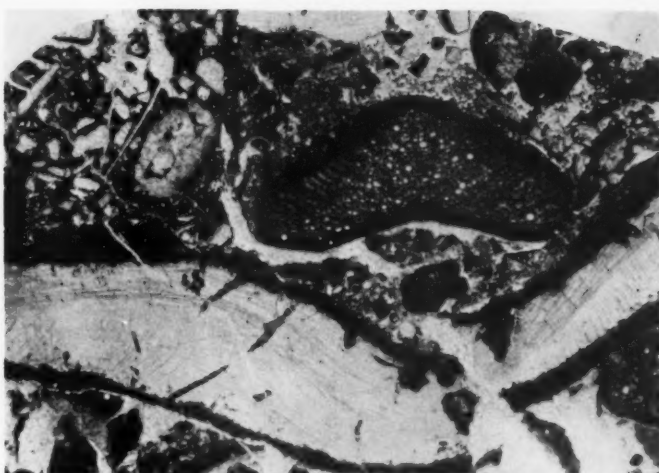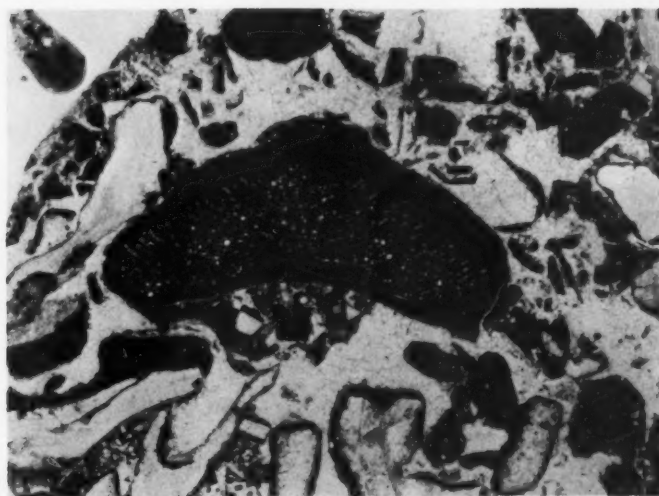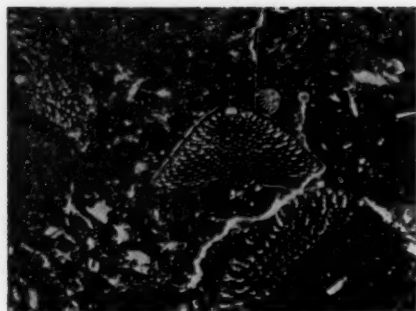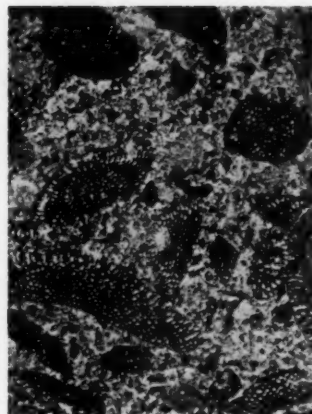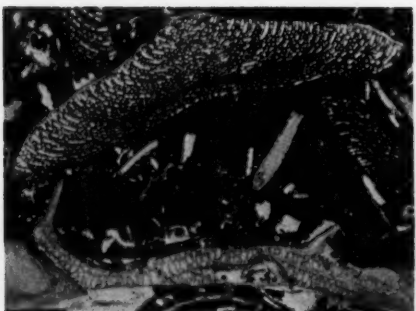
PLATE 5
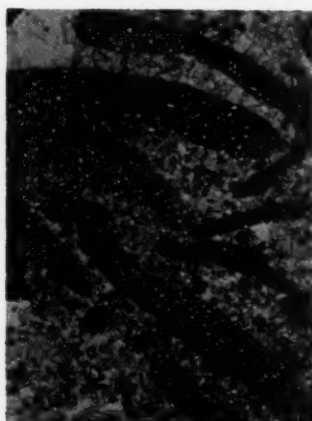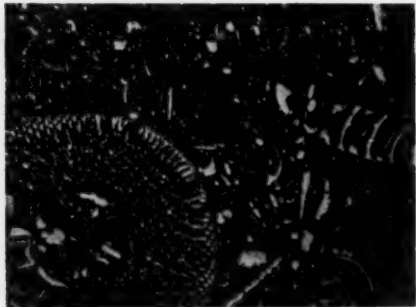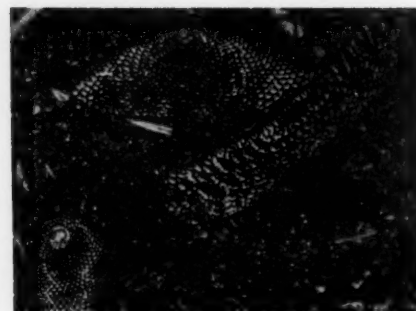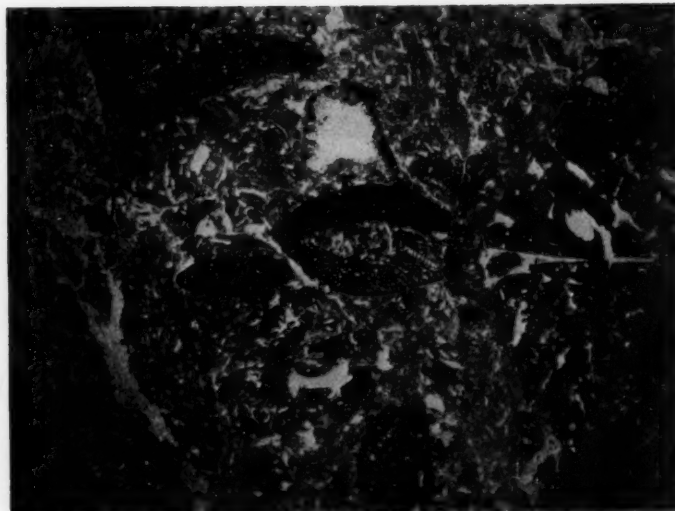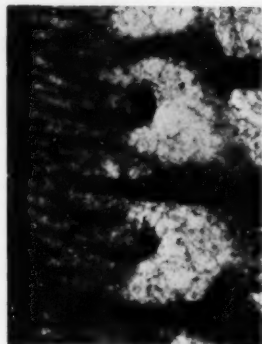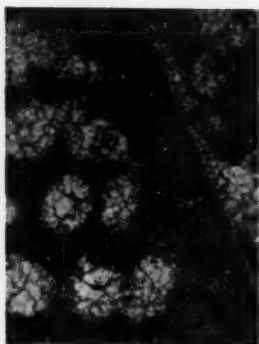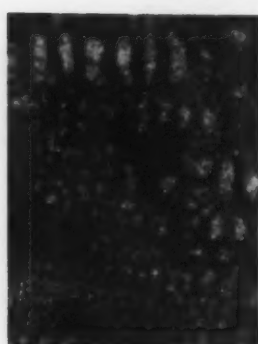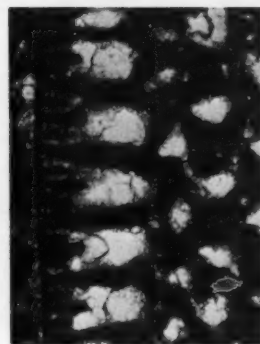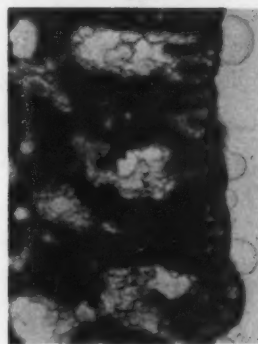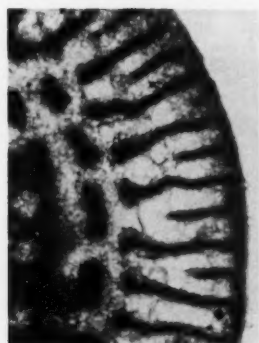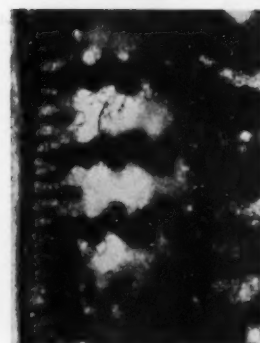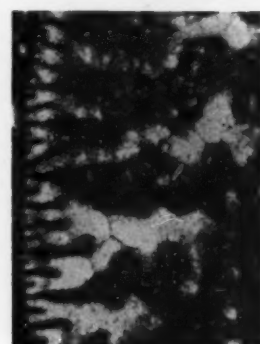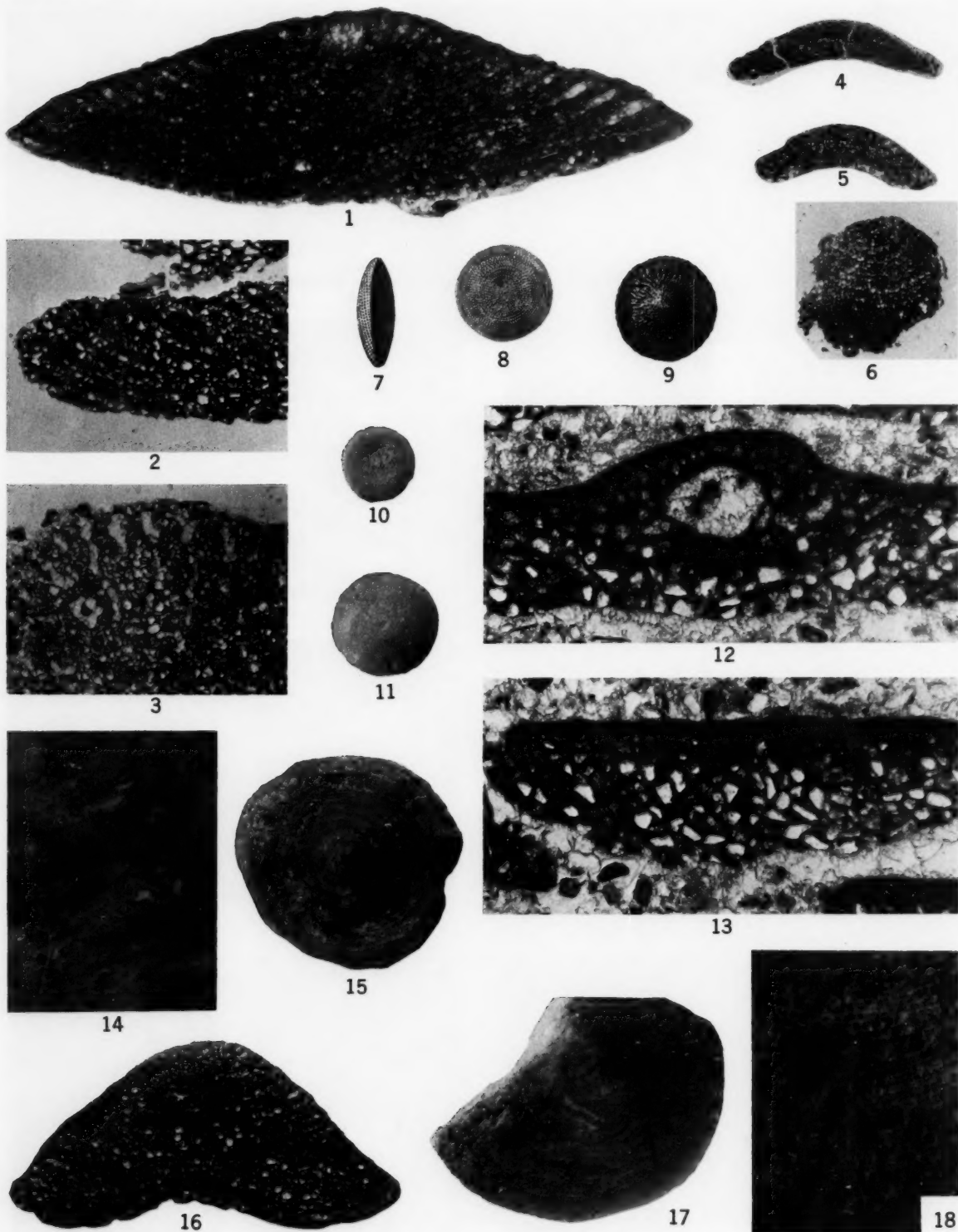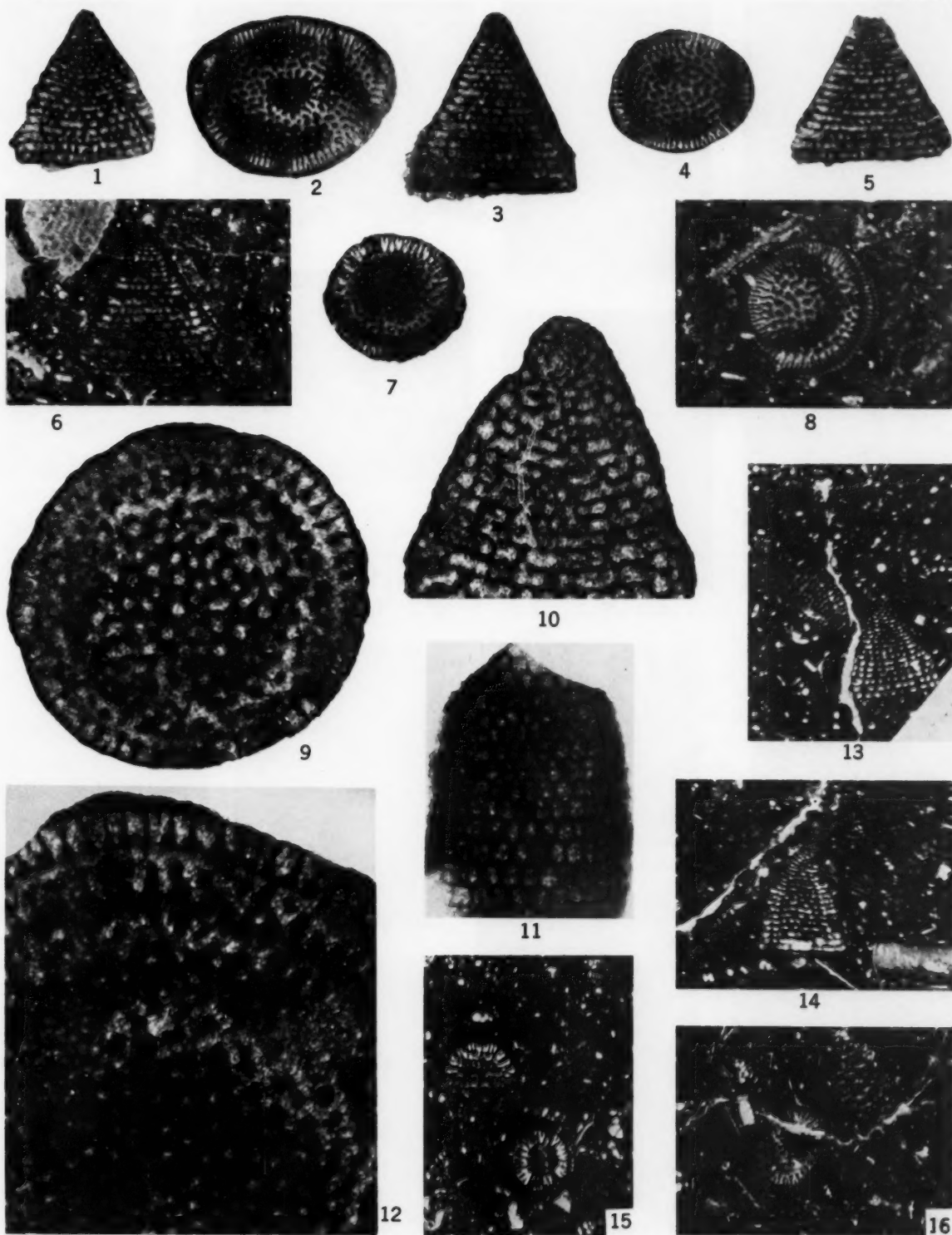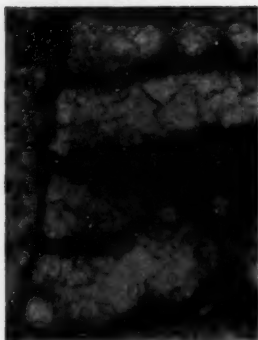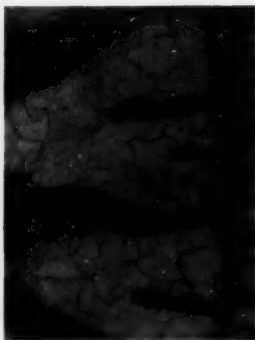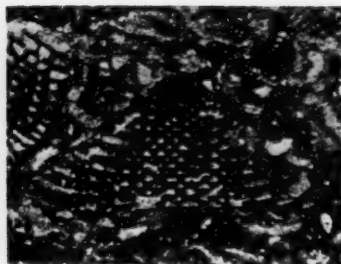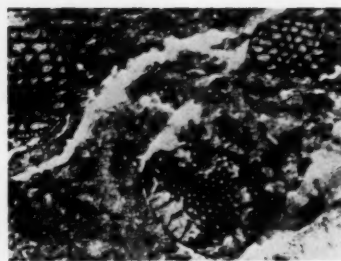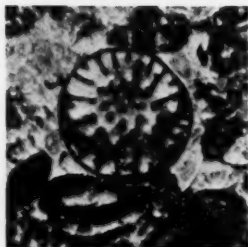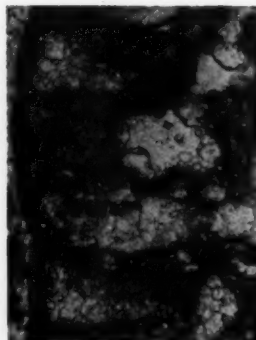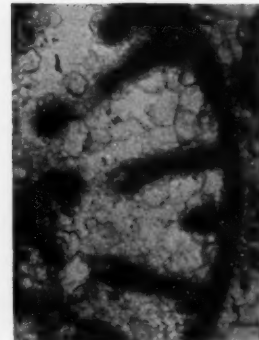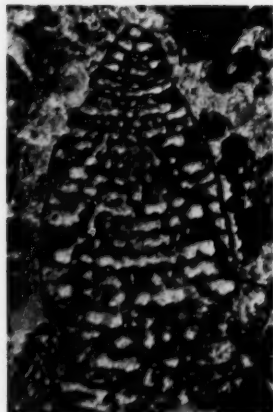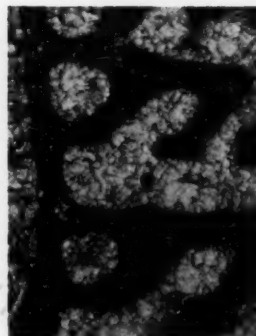
ABSTRACT: *Recently discovered pollen grains with asymmetrically ridged ektexines from the Chinle formation (Upper Triassic) represent the extant genus* Ephedra. *The holotype specimen of* Equisetosporites chinleana *Daugherty is also a conspecific* Ephedra *pollen grain, and the species is transferred to form the new combination* Ephedra chinleana *(Daugherty) R. A. Scott. Since this species was its genotype, the genus* Equisetosporites *Daugherty should be abandoned.*

Pollen of Ephedra from the Chinle formation (Upper Triassic) and the genus Equisetosporites

RICHARD A. SCOTT

U.S. Geological Survey
Denver, Colorado

INTRODUCTION

Unusual pollen grains representing the modern gnetalean genus *Ephedra* are present among plant microfossils from the Chinle formation, of Late Triassic age, in Utah and Arizona. This pollen and spore flora is under study and will be described later; meanwhile, the age and unusual morphology of the *Ephedra* pollen and its relationship to the putative genus *Equisetosporites* Daugherty make separate description of it desirable.

The assistance of the following persons is gratefully acknowledged: E. S. Barghoorn, who loaned modern *Ephedra* pollen slides; R. W. Chaney, who furnished a matrix sample from the type locality of *Equisetosporites chinleana;* E. C. Davidson, who helped collect the material from Circle Cliffs, Utah and supplied geologic information about this occurrence; W. L. Fry, who loaned the holotype specimen of *Equisetosporites*; and J. C. Stacy, who prepared the text-figures. Publication of this paper is authorized by the Director, U. S. Geological Survey.

SYSTEMATIC DESCRIPTION

Class GYMNOSPERMAE
Order GNETALES
Family EPHEDRACEAE
Genus EPHEDRA Tournefort ex Linnaeus, 1737

Ephedra chinleana (Daugherty) R. A. Scott,
new combination

Plate 1, figures 1, 8, 10–12, 14–18; text-figures 1–2

Equisetosporites chinleana DAUGHERTY, 1941, Carnegie Inst.
    Washington, Pub. 526, p. 63, pl. 24, fig. 4.

Emended description: Pollen ellipsoid, 40–80μ long, 25–50μ in diameter as seen in compressed form; with 12 to 25 thickened ektexinous ridges, alternating with furrows, extending meridionally, often with a slight spiral toward the poles of the major axis; adjacent ridges discontinuous, 3–5μ wide, semicircular in cross section, with numerous columellae.

Ridges of most grains converging subterminally, forming four distinct areas of convergence on the grain.

The two areas of convergence near each pole opposite, to subopposite, separated by 1–3 polar ridges that extend with a slight spiral almost around the grain in the direction of the major axis; polar ridges, originating as marginal ridges on one side of an area of convergence, extending between the areas of convergence at the opposite end of the grain, and leading back on the other side of the grain toward the original end to form marginal ridges on the side of the area of convergence diagonally opposite the point of origin; thus, the grain is asymmetric. Polar ridges sometimes joined near the poles, in some grains partially reflexed by extension of subopposite convergence points past the midline of the grain. In rare specimens, all bands fuse to form a single, simple polar area as in most pollen of modern *Ephedra*. Endexine thin-walled (less than 1μ), smooth.

Occurrence: Chinle formation (Upper Triassic). Arizona: Daugherty's (1941) locality P3901–2, Petrified Forest National Monument, the type locality. Utah: U.S.G.S. Paleobot. loc. no. D1341, NW corner of SE 2½ min. square of the Circle Cliffs 1 SW quad., Garfield Co.; U.S.G.S. Paleobot. loc. no. D1344, near center of sec. 2, T. 35 S., R. 18 E., San Juan Co.; U.S.G.S. Paleobot. loc. no. D1442, Capitol Reef area, Wayne Co.

Holotype: University of California Museum of Paleontology, Paleobotany Series, no. 1562.

GEOLOGIC OCCURRENCES

Pollen of *Ephedra* was first recognized in the Chinle formation in material from Circle Cliffs, Garfield County, Utah. Abundant examples of the species were obtained from a lens of coal in a layer of white sandstone which here rests directly on the Moenkopi formation. This sandstone is thought to be located in the Shinarump member of the Chinle formation (E. C. Davidson, personal communication).

Pollen of the species was later discovered in organic shales from two additional localities in Utah, both in the lower part of the Chinle formation. Daugherty's locality P3901–2 in the Petrified Forest National
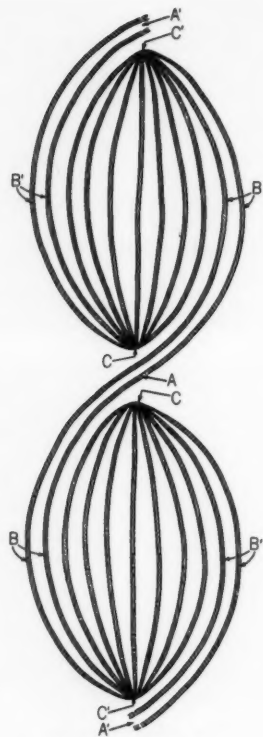
TEXT-FIGURE 1

Ephedra chinleana (Daugherty) R. A. Scott, new comb. Diagram of the organization of the ektexine ridges. The ovoid grain is shown cut medianly along the major axis, with the two halves remaining attached at one pole and the free end of each half opened outward. Thus A′ at the top of the diagram is equivalent to A′ at the bottom and the two ridges shown broken at the top and bottom would be continuous. A and A′, poles; B and B′, polar ridges; C and C′, convergence areas.

Monument, Arizona, is apparently also in the lower part of the Chinle formation (Stagner, in Daugherty, 1941). The known stratigraphic range of this fossil *Ephedra* species is limited to the Upper Triassic.

MORPHOLOGY AND AFFINITIES

The outstanding characteristics of this fossil pollen are its alternating ridges and furrows and the unusual asymmetry of the ridge pattern. The ovoid grains range from about 40 to 80μ in length; the maximum diameters of unexpanded grains range from about 25 to 50μ. The typical ratio of length to diameter is approximately 5 to 3. The ridges typically are wider (3–5μ) than the intervening furrows (1μ). Some grains expand markedly in processing, causing extreme separation of the ridges (pl. 1, figs. 8, 12, 16).

The pollen wall consists of a thin (less than 1μ) endexine and a thick (as much as 3μ) discontinuous ektexine
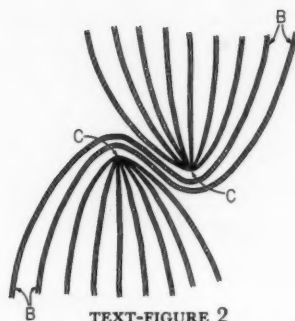
TEXT-FIGURE 2

Ephedra chinleana (Daugherty) R. A. Scott, new comb. Diagram of grain with subopposite convergence areas. View and lettering as in text-figure 1.

that forms the ridges (pl. 1, fig. 14). When both layers are intact, they appear to be connected by conspicuous columellae which project slightly below the inner surface of the ektexine (pl. 1, fig. 8). The endexine separated easily from the ektexine, probably because its attachment was at the inner tips of the columellae. In many fossil grains the endexine is no longer present; owing to its tenuous nature it seldom survived the degradative processes operative in the coal-forming environment (U.S.G.S. Paleobot. loc. no. D1341). It is more commonly present in specimens from gray shale (U.S.G.S. Paleobot. loc. no. D1442). When present, the endexine, although still retained within the ektexine, may be detached and shrunken (pl. 1, fig. 15). This condition is important to the interpretation of the genus *Equisetosporites* presented later in this paper.

The basic asymmetry of the grain derives from the orientation of the polar ridges, so called because each set of ridges crosses a pole, terminating at opposite sides of the opposing convergence areas at the other end of the grain. These relationships, difficult to describe, may be made clear diagrammatically (text-fig. 1). There may be variation from one to three in the number of polar ridges in each set, and in the extent of joining to other ridges (pl. 1, figs. 8, 16), but the basic arrangement is as diagrammed.

In many grains, possibly as a result of crowding during development, the convergence areas are not exactly opposite and may extend onto the opposite half of the grain (text-fig. 2). This extension imparts a spiral twist to the bands, causing them to look somewhat like miniature charophyte gyrogonites (pl. 1, figs. 10, 11). In more distorted grains the normally opposite or subopposite convergence areas may be displaced as much as 90 degrees (pl. 1, fig. 12).

This fossil pollen is acolpate in the sense of Steeves and Barghoorn (1959). However, the grains tend to come open at the sides along the polar ridges (pl. 1, fig. 15); perhaps these regions functioned as colpi.

The polycolpate pollen in certain dicotyledonous families, *e.g.* Polygalaceae and Lentibulariaceae, resembles the ridged Chinle form, but detailed examination shows the similarity to be superficial. In addition, the Triassic age of the fossil material makes it unlikely that dicotyledonous plants are represented.

The spores of some ferns, particularly in the family Schizaeaceae, are ridged like the Chinle fossil form. Most schizaeaceous spores are trilete; however, monolete spores occur in the family and potentially could be confused with the fossil. The monolete spore of *Schizaea laevigata* Matt., figured by Selling (1944, plate 3, fig. 24) shows a criss-cross appearance of its ridges comparable to that seen in these Triassic grains. However, excellent preservation and large number of specimens examined (several hundred) have made it possible to eliminate the possibility that the Chinle form is a monolete spore. Ridged spores are common in Mesozoic sediments and have been described under such generic names as *Appendicisporites* Weyland and Krieger and *Cicatricosisporites* R. Potonié and Gelletich. These genera have not been recognized in sediments as old as Triassic.

Modern pollen having an alternation of ridges and furrows like that of the Chinle fossil is produced by the gnetalean genera *Welwitschia* and *Ephedra*. Pollen of the third gnetalean genus, *Gnetum*, lacks ridges and bears little resemblance either to *Welwitschia* or *Ephedra*. The monocolpate pollen of the single species of *Welwitschia* has one furrow much more prominently developed than the others. In *Ephedra*, the furrows normally are equally developed; this pollen is most like the Chinle material.

Steeves and Barghoorn (1959) have studied the pollen of most modern species of *Ephedra*. They divided the species into four partially intergrading groups based upon number and structure of ridges, size and form of intervening furrows, and presence or absence and structure of the colpi. Of these groups, their Type D is of chief interest here. Steeves and Barghoorn describe it as follows (p. 247):

"The grains of Type D are characterized by wide, low, gently rounded, ektexinous ridges which measure $2–3\mu$ in height and $3.5–9\mu$ in width. In polar view the ridges appear semicircular in outline, in contrast to the triangular outline of the ridges in the three preceding groups. The furrows which abruptly flank the ridges at their bases are narrow ($1–3.5\mu$), unbranched and straight. They are the result of extreme thinning of the ektexine. No colpi are present.

Within this group occurs the species which possesses the greatest number of ridges, *E. alata* (Chart 2). Moreover, the average number for the group as a whole is greater than in Types B and C. Pollen grains of the D type are quite distinctive and readily separable from the other pollen types. However, within some species, possessing predominantly Type D grains, occasional grains of the B and C types occur. None of the seven species possessing D type grains shows the least tendency toward the A type."

The Chinle pollen has the following features in common with modern *Ephedra* pollen of Type D: 1) numerous, wide, low ridges having semicircular cross sections; 2) narrow, unbranched, straight furrows; 3) absence of colpi.

The major problem in assigning this Chinle form to *Ephedra* is the arrangement of the ridges at the poles. The polar area is difficult to examine in *Ephedra* pollen because most grains in a preparation are oriented with their long axes parallel to the slide. Welten (1957, pl. 3, fig. 43) has figured a polar view of *E. strobilacea* Bunge, a Type D species, showing that the ridges do not all run intact to the poles, but may fuse below the poles so that two or more ridges form a single ridge which then unites with others at the pole. More involved coalescences of the ridges into subterminal convergence areas exactly like those of the fossil species have been observed in occasional grains of the modern species *E. wraithiana* I. M. Johnson and *E. foliata* Boiss. and Kotschy ex. Boiss., (pl. 1, figs. 5, 9). Conversely, occasional pollen grains in the Triassic preparations have fewer ridges that appear to lead directly to the poles as in most modern grains (pl. 1, fig. 7).

One of the attributes of modern *Ephedra* pollen is variability in morphology, both within groups of species and within a species. Steeves and Barghoorn (1959) found intergrading in characteristics to an extent that their four groups are not all mutually exclusive, although their A and D types, representing morphological extremes in the pollen of the genus, do not overlap. With the existence established (pl. 1, figs. 5, 9) of some asymmetrical grains in modern species, as well as occasional symmetrical grains in the dominantly asymmetrical fossil population (pl. 1, fig. 7), it appears that we are dealing with two extremes, temporally separated, of a range of potential morphological expression in the genus.

Further, with the patterns of variability and diversity of structure within modern *Ephedra* in mind, the differences between the asymmetrical ridge pattern of *E. chinleana* and the essentially simple polar organization of most modern *Ephedra* pollen seem less significant than the varied pollen morphologies among modern *Ephedra* species. Consequently, the Triassic species has been assigned to the extant genus *Ephedra*.

The geologic record of the Gnetales, revealed chiefly from fossil pollen, is extensive. Grains resembling those of *Ephedra* have been reported from the Permian of Oklahoma (Wilson, 1959). Permian forms of presumed gnetalean affinities include bisaccate grains with ridged bodies, giving rise to speculation that *Ephedra* and *Welwitschia*, which may have apparently residual bladders, have evolved by reduction from bladdered forms (Tchigouriaeva, 1954). Although *Ephedra* pollen can be identified with certainty, *Welwitschia* pollen cannot be separated from some *Ephedra* grains because of the occurrence of occasional atypical *Ephedra* pollen with one well developed colpus (Beug, 1956). *Ephedra* pollen is known from Cretaceous (*e.g.* Steeves and Barghoorn,

PLATE 1

All figures magnified about 750 diameters except no. 14, which is magnified about 1300 diameters. U.S.G.S. pollen numbers consist of the locality number – sample number – slide number. Microscope coordinates are given in millimeters horizontally, then vertically, from the lower right corner of the cover slip. The slide numbers for all Recent *Ephedra* species refer to the Harvard University Pollen Collection.

1 *Ephedra chinleana* (Daugherty) R. A. Scott, new comb.

D1341–1–99; coord. 10.6 × 5.7; a relatively straight ridged grain with prominent columellae.

2 *Ephedra torreyana* S. Wats.

HP–1049; Recent, note columellae.

3 *Ephedra reedii* Cory

HP–1047; Recent; a many ridged grain; crisscross appearance is due to tilting of the major axis.

4 *Ephedra pedunculata* Engelm. ex S. Wats.

HP–1071; Recent.

5 *Ephedra wraithiana* I. M. Johnson

HP–1078; Recent; ridges of this grain are arranged asymmetrically with polar ridges and subopposite convergence areas as in the fossil *E. chinleana*.

6 *Ephedra reedii* Cory

HP–1047; Recent; polar view showing simple union of the ridges at the pole.

7 *Ephedra* sp.

D1341–1–87; Coord. 13.0 × 5.0; Triassic fossil grain with wide ridges and simple polar organization comparable to that of most modern grains.

8 *Ephedra chinleana* (Daugherty) R. A. Scott, new comb.

D1341–1–100; coord. 7.9 × 12.6. Greatly expanded grain showing relationship between polar ridges and convergence areas. Compare with text-fig. 1. Note columellae projecting inward from the inner surface of the ektexine. The endexine is missing from this and all other figured specimens except figs. 14, 15, 17, 18.

9 *Ephedra foliata* Boiss. & Kotschy ex. Boiss.

HP–1065; Recent; polar view showing polar ridges and subopposite convergence areas as in the fossil species *E. chinleana*.

10 *Ephedra chinleana* (Daugherty) R. A. Scott, new comb.

D1341–1–101; coord. 25.6 × 20.6; grain with narrow, markedly spiralling ridges.

11 *Ephedra chinleana* (Daugherty) R. A. Scott, new comb.

D1341–1–102; coord. 29.3 × 2.7; grain with wide, spiralling ridges; this unexpanded grain shows the relatively narrow furrows.

12 *Ephedra chinleana* (Daugherty) R. A. Scott, new comb.

D1341–1–103; coord. 17.8 × 9.9; ridges on opposite sides of the expanded grain are at right angles to each other.

13 *Ephedra foliata* Boiss. & Kotschy ex. Boiss.

HP–1065; Recent; ridges on opposite sides of the grain are at right angles to each other; compare with fig. 12.

14 *Ephedra chinleana* (Daugherty) R. A. Scott, new comb.

D1341–1–104; coord. 9.5 × 5.2; magnification × 1300; portion of a grain in polar view showing thin endexine and discontinuous ektexine forming ridges which are semicircular in cross section.

15 *Ephedra chinleana* (Daugherty) R. A. Scott, new comb.

D1442–1–3; coord. 38.3 × 15.9; grain retaining the endexine; the two sides of the ektexine have separated along the polar ridges and are displaced slightly.

16 *Ephedra chinleana* (Daugherty) R. A. Scott, new comb.

D1341–1–105; coord. 10.1 × 9.5; polar view of an expanded grain with subopposite convergence areas, imparting a spiral pattern to the meridional ridges.

17 *Ephedra chinleana* (Daugherty) R. A. Scott, new comb.

D1442–1–3; coord. 17.2 × 3.0; polar view of a grain retaining the endexine; the convergence areas show extreme displacement.

18 *Ephedra chinleana* (Daugherty) R. A. Scott, new comb.

Univ. Cal. Mus. Pal., Paleobot. Ser. no. 1562; holotype; this photo is oriented differently than in Daugherty's (1941) plate 34, fig. 4. Here the grain is placed so that convergence areas appear at upper and lower portions of the photo. Compare with figs. 15, 17.
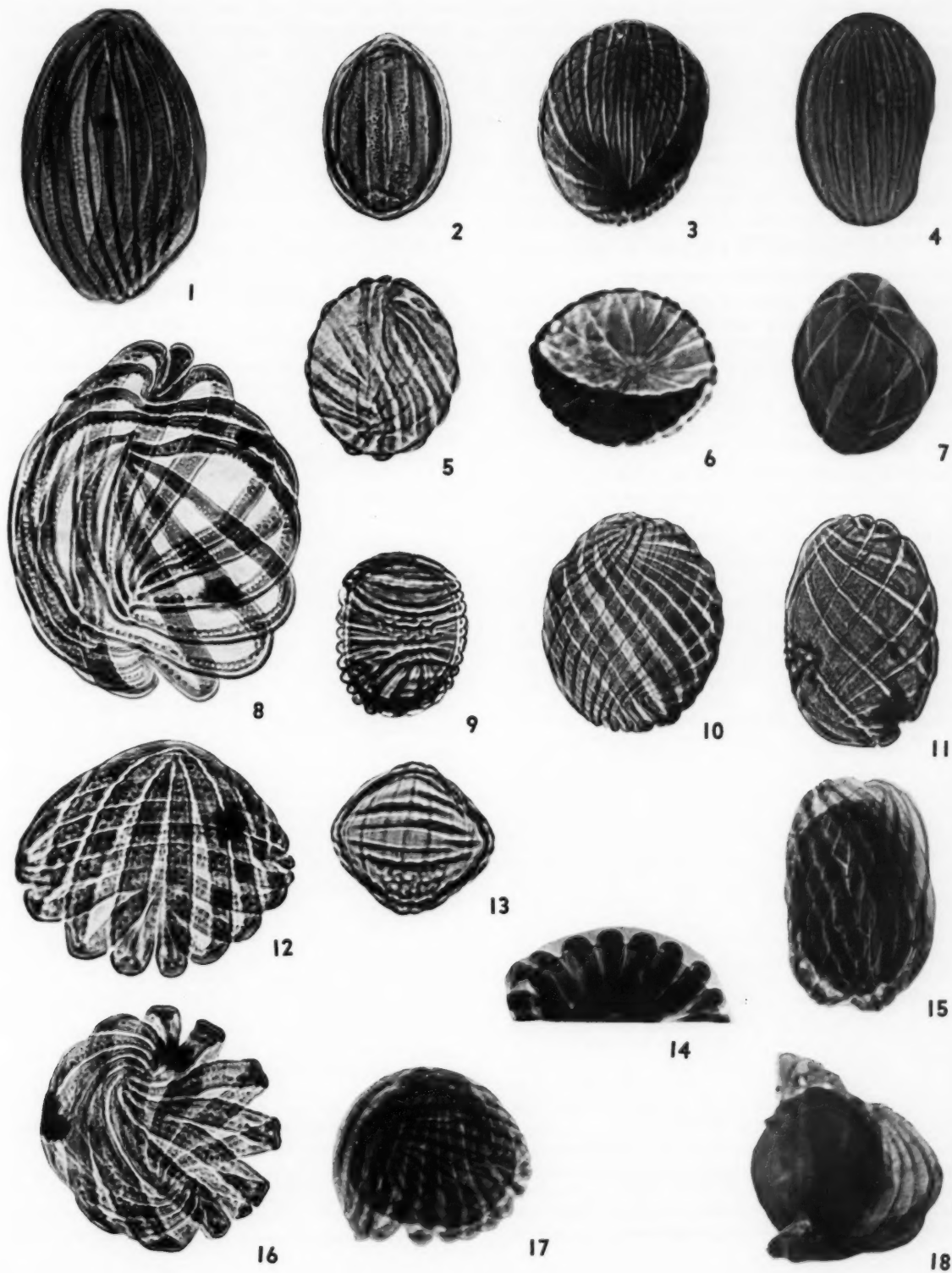
1959; Kuyl, Muller, and Waterbolk, 1955) and Tertiary (*e.g.* Cookson, 1956; Wodehouse, 1934) sediments. Some material identified as gnetalean may prove to be schizaeaceous fern spores, as Bolkhovitina (1959) has found for certain species originally assigned to the genera *Ephedripites* and *Welwitschiapites*.

The long geologic history suggested by the structural specialization of modern *Ephedra* is fully borne out by the fossil record. This occurrence of *Ephedra* in the Triassic is a part of the accumulating evidence that *Ephedra* must be regarded, along with *Gingko*, as one of the oldest of extant plant genera.

AFFINITY OF "EQUISETOSPORITES" DAUGHERTY

After studying the grains of *Ephedra* from the Circle Cliffs locality, I noted a similarity of their ridges to the elaters shown in the photograph of the holotype (and only) specimen of *Equisetosporites chinleana* Daugherty (1941, pl. 34, fig. 4), the type species of the genus. Professor W. C. Fry, University of California, kindly loaned me Daugherty's slides, including the holotype of *E. chinleana*, for examination.

The holotype of *Equisetosporites chinleana* Daugherty from the Chinle formation was described as a spherical spore, 36 microns in diameter, thin walled and with two tightly wrapped elaters, which is indistinguishable from spores of modern *Equisetum* (Daugherty, 1941). Schopf, Wilson, and Bentall (1944) reexamined the type specimen and, although they did not formally emend the genus, furnished a more complete description of it. They concluded that there probably were four elaters present, which tended to encircle the body spirally. Nilsson (1958), without examining the original material, has also given a new diagnosis of the genus without formally emending it.

My interpretation of the holotype specimen is that it is a grain of asymmetrical *Ephedra* pollen, conspecific with the material described earlier in this paper. The so-called elaters are the ridged ektexine, in this example partially disassociated into two portions along the polar ridges, and seen from a semipolar view (pl. 1, fig. 18). The course of the "elaters" can be traced by careful focusing through the grain; at their ends they unite into the convergence areas typical for the other Chinle *Ephedra* pollen instead of being free, as are the elaters of *Equisetum*. Although this convergence of the "elaters" is clear, the specimen is exceedingly difficult to photograph because of the great difference in optical density between the translucent ridges and the dark, central endexine. G. O. W. Kremp, E. B. Leopold, J. M. Schopf, and R. H. Tschudy, who have examined the specimen while it has been on loan to me, agree that the "elaters" are like the ridged ektexine of the form here considered to represent *Ephedra*.

The darker "spore" encircled by the ridged ektexine posed another problem. My original interpretation, after having examined only Circle Cliffs, Utah, material of the Triassic *Ephedra*, in which endexines rarely are preserved, was that the holotype specimen consisted of

an accidental juxtaposition of the *Ephedra* ektexine and an alete spore, possibly fungal. Pollen grains of *Ephedra* from another Chinle locality (D1442), however, commonly contain the endexines. Like the central "spore" of Daugherty's holotype specimen, these endexines are dark, thin-walled, and often have become detached from the ektexine and may have shrunk (pl. 1, figs. 15, 17). By comparison with this material it is apparent that the holotype of *Equisetosporites chinleana* is a grain of the pollen here identified as *Ephedra*.

This interpretation is strengthened by finding specimens clearly belonging to the asymmetric *Ephedra* species in shale from the type locality of *Equisetosporites chinleana*, kindly furnished from the University of California collections by R. W. Chaney. Accordingly, the species name is here transferred to form the new combination *Ephedra chinleana* (Daugherty) R. A. Scott with Daugherty's specimen remaining as the holotype. The genus *Equisetosporites* should be abandoned.

BIBLIOGRAPHY

BEUG, H. J.
1956 – *Pollendimorphismus bei Ephedra*. Die Naturwissenschaften, vol. 43, pp. 332–334.
BOLKHOVITINA, N. A.
1959 – *Personal communication to G. O. W. Kremp 4/27/59*. Cited in Catalog Fossil Spores and Pollen, vol. 8, pp. 90–92.
COOKSON, I. C.
1956 – *Pollen grains of the Ephedra type in Australian Tertiary deposits*. Nature, vol. 177, no. 4497, pp. 47–48, text-figs. 1–4.
DAUGHERTY, L. H.
1941 – *The Upper Triassic flora of Arizona*. Carnegie Inst. Washington, Pub. 526, 108 pp.
KUYL, O. S., MULLER, J., AND WATERBOLK, H. T.
1955 – *The application of palynology to oil geology, with special reference to western Venezuela*. Geol. Mijnb., n. s., vol. 17, no. 3, pp. 49–76, pls. 1–4, text-figs. 1–7.
NILSSON, T.
1958 – *Über das Vorkommen eines mesozoischen Sapropelgesteins in Schonen*. Lunds. Univ. Årsskr., n. s., vol. 54, no. 10, pp. 1–111, pls. 1–8, text-figs. 1–12, tables 1–5, map.
SCHOPF, J. M., WILSON, L. R., AND BENTALL, R.
1944 – *An annotated synopsis of Paleozoic fossil spores and the definition of generic groups*. Illinois State Geol. Survey, Rept. Inv., vol. 91, pp. 1–73.
SELLING, O. H.
1944 – *Studies in the recent and fossil species of Schizaea, with particular reference to their spore characters*. Meddel. från Göteborgs Bot. Trädg, vol. 16, pp. 1–112.
STEEVES, M. W., AND BARGHOORN, E. S.
1959 – *The pollen of Ephedra*. Jour. Arnold Arb., vol. 40, pp. 221–225.
TCHIGOURIAEVA, A. A.
1954 – *Structure du pollen des Gnetales*. Grana Palynologica, vol. 1, pp. 95–98.
WELTEN, M.
1957 – *Ueber das glaziale und spätglaziale Vorkommen von Ephedra am nordwestlichen Alpenrand*. Schweiz Bot. Ges., Ber., vol. 67, pp. 33–54, 3 pls., 3 text-figs.
WILSON, L. R.
1959 – *Geological history of the Gnetales*. Oklahoma Geol. Notes, vol. 19, no. 2, pp. 35–40, pl. 1.
WODEHOUSE, R. P.
1934 – *A Tertiary Ephedra*. Torreya, vol. 34, pp. 1–4.

ABSTRACT: *Formational names of rock units of the Lower Tertiary Libya Group in Egypt are introduced. The planktonic foraminifera of the Thebes Formation, Libya Group from the type locality at Luxor, Egypt are described and illustrated. The planktonic foraminifera found in the underlying Esna Shale are described. The Esna Shale in Luxor, having a fauna of sharply keeled* Globorotalia *species, is considered to be of upper Paleocene (Landenian) age. The overlying Thebes Formation contains a planktonic fauna of smoother and more compressed types:* Globorotalia thebaica, *n. sp.,* G. imitata Subbotina *and* G. planoconica *Subbotina. The Thebes Formation is believed to represent the open sea facies of the Egyptian lower Eocene (Ypresian).*

Planktonic foraminifera from the Thebes Formation, Luxor, Egypt

RUSHDI SAID
Cairo University
Egypt, U.A.R

INTRODUCTION

Lower Tertiary rocks have a wide distribution in Egypt. Although they were first recognized in Egypt by Delanoue (1868), the first serious and systematic study of these rocks dates back to Zittel (1883), who accompanied the Rohlf's Expedition to the Libyan Desert. In this monumental work, Zittel equated the lower Eocene with the "Libysche Stufe" a term that was accepted in geological literature. The term "Libyan" was used, at that time, to designate rocks of a particular age, the lower Eocene. Zittel further subdivided the "Libysche Stufe" into an "Unterlibysche Stufe" which was considered early lower Eocene and an "Oberlibysche Stufe" which was considered late lower Eocene. Zittel further equated the middle Eocene with the "Mokattam Stufe."

The term Libyan and Mokattam, although used as time units, are in fact rock units that are defined primarily on the basis of gross lithologic characters and geologic occurrence. I shall demonstrate in this and subsequent papers that they do not coincide, in many cases, with units that represent particular intervals of time. Concepts of geologic time-span play no part in differentiating or delimiting the boundaries of these rock units. The accumulation of sediments assigned to a particular unit may have begun earlier in some localities than in others, and it may have ended sooner or lasted longer in different localities.

A classification of the rock units of the Libya Group in Egypt follows. In preparing these notes, I have been guided by the stratigraphic commission reports and recommendations regarding the naming and ranking of units, the priority of names, and the designation of type localities.

THE LIBYA GROUP

Zittel's "Libysche Stufe" is the unit that overlies the chalk which is "sometimes shaly-marly or sandy in its lower beds." This unit is here given group status because it includes several well-established formational divisions. Its name is here changed to conform with the recommendations of the Stratigraphic Commission (1956) and is given a substantive name rather than an adjectival one.

Zittel mentions no type locality for his "Libysche Stufe" but states that this unit is primarily developed on the "left" side of the Nile and seems also to be widely distributed in stretches to the east of the Nile. In spite of the fact that, in his discussion, he mentions that the "schönsten Profil" of the Libya Group is to be found in Farafra, one cannot use this section as a type locality, because the entire section in Farafra represents only a fraction of the Group. Probably what interested Zittel in this section was that it gave him a chance to study the Cretaceous-Lower Tertiary contact, a study that led him to his contention that "there is no sharp line of demarcation between the Cretaceous and Tertiary and no disturbance in the stratigraphical succession". This contention was accepted in the literature for a very long time and influenced the thinking of practically every worker on the subject. This section cannot be taken as a type, and, in fact, no other single section covers the entire succession of the Libya Group as conceived by Zittel. The acceptance of this unit is, therefore, questionable. However, because the term is well established, it will be retained here and the terms "Lower Libyan" and "Upper Libyan" will be dropped since they indicate no geographic locality and do not conform, either in construction or in meaning, to modern concepts of stratigraphic classification.

LEGEND.

▦ LIMESTONE WITH FOSSILS.

▤ LIMESTONE.

◇ MARL.

△ FLINT.

▭ SHALE.

TEXT-FIGURE 1

The Libya Group consists of the following formations, from base to top:

Esna Shale

The term Esna Shale was published by Ball as early as 1900 in comparing the shales above the Chalk in Kharga Oasis with those "exposed in the Nile Valley in the neighbourhood of Esna, to which the designation 'Esna Shales' has been applied in reports of the Geological Survey." However, the credit for coining the term is given to Beadnell who apparently introduced the term in these reports and who described this formation fully in 1905. The type locality by designation is Gebel Oweina, opposite Esna, lying some 8½ kilometers northeast of the Sebaia railway station.

The term Esna Shale is here used only for the succession of "laminated green and grey, shaly clays" that overlie the Chalk and underlie the Thebes Formation or the Farafra Limestone (*vide infra*). This is a uniform unit that has great geographic distribution, as it has been recorded as far west as the oases, and as far east as the extremity of Sinai.

There has been a tendency in recent years to revive the practice started by Hume (1912) of calling this unit the "Upper Esna Shale" and assigning to the "Lower Esna Shale" the succession of grey laminated shales that underlie the Chalk, which were described by Zittel as "Grünliche und Aschgraue Blätterthone" (Nakkady, 1957). This practice is here condemned for it neither conforms to the original use of this term nor does it conform with modern concepts of stratigraphic nomenclature. Furthermore, the matter is even more complicated by the fact that some authors use the terms "Upper and Lower Esna Shale members" to designate those units that are separated by a middle limestone member that consistently runs through the shales above the Chalk.

The Esna Shale has, in recent years, been the subject of micropaleontological studies (Nakkady, 1949, 1950, 1951, 1957; Osman, 1954; Said and Kenawy, 1956). No other unit in the Egyptian succession has been described from so many different localities and assigned to so many different places in the geologic column. Because of this situation Nakkady (1949, 1950) and Osman (1954) have suggested the abandonment of the term entirely.

The age of this unit is Landenian (upper Paleocene) at its type locality, and is characterized by the presence of a sharp-keeled *Globorotalia* assemblage.

Farafra Limestone

The type locality of this new formation is at el-Guss Abu Said. This term designates buff colored beds of hard, medium to coarse crystalline alveolinid limestones that top the Esna Shale at el-Guss Abu Said, Farafra. They form a cliff 63 meters high. This unit has been amply described by Zittel (1883), Beadnell (1900),
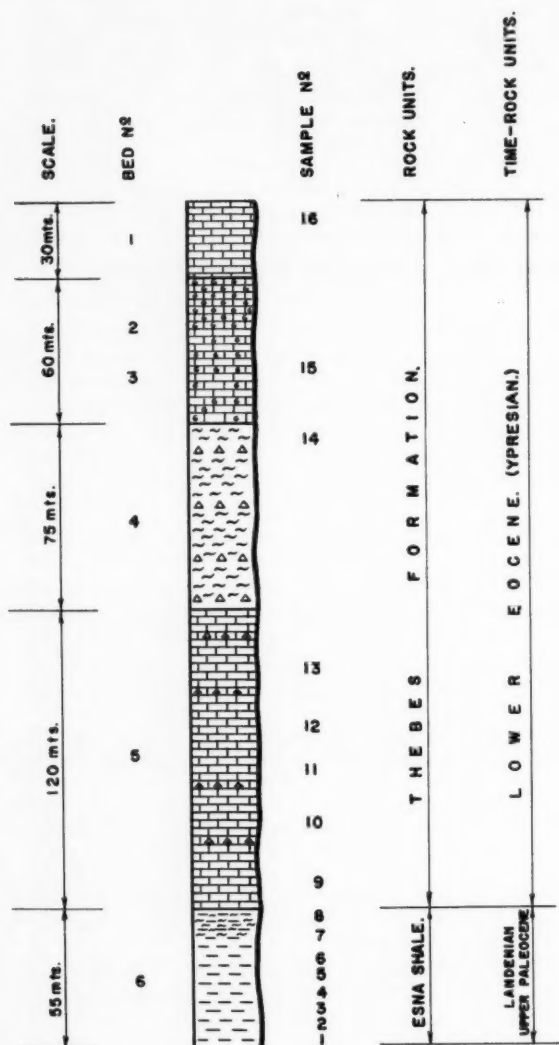
LeRoy (1953), Reichel (1936), and Schaub (1951). An assessment of the biologic and lithologic characters of this formation will be published shortly (Said and Kerdany, in press).

The Farafra Limestone is recorded from only a few localities; in the northern Galala plateau region (Fourtau, 1902), in the south of Assiut and in Gebel Krer, Sinai. As these few but widely separated areas show, the unit has a wide geographic distribution. In the type locality this unit is considered to be Ypresian in age and probably represents the reefal facies of the lower Eocene.

Thebes Formation

This is a formational name which is equivalent to the *Operculina* limestone of older authors, and of Nakkady, 1957; and "Limestone with flint," of many authors.

The type locality of this new formation is at Gebel Gurnah, opposite Luxor. This term is applied to the 290-meter thick limestone section with many flint bands that overlies the Esna Shale at Thebes. This paper is devoted to a study of this formation and an analysis of its lithologic and biologic aspects. This formation is Ypresian in age at the type locality and probably represents the open sea facies of this age in Egypt. This facies has been described by Hume (1911) as the "Luxor type" of basal Eocene strata in contradistinction with the seemingly unfossiliferous white limestones of the "Quena type." The Thebes Formation is of wide extent and has been recorded from the Nile Valley, the Eastern Desert and Sinai.

Minia Formation

Minia Limestone: This is a new formational name equivalent to "Alveolinen Kalk" or "Oberlibysche Stufe" of Zittel and subsequent workers. This name designates beds of white alveolinid limestones, 30 meters thick, that underlie the light green to buff nummulitic limestones containing *N. gizehensis*. The type locality is on the eastern side of the Nile at Minia, Upper Egypt. This area has been chosen as the type locality in preference to nearby Beni Hassan, which was chosen as an "example" of the lower Lutetian by Schaub (1951), because the Minia section is more fossiliferous and accessible and also has page precedence in Zittel's work. For a full description of this section see Zittel (1883) and Cuvillier (1930). The age of this formation at the type locality is lower Lutetian. It probably represents the reefal facies. Up to the present time the open sea facies of the lower Lutetian has not been described from surface exposures.

The Minia Limestone is of considerable geographic extent. At Assiut, a more complete section some 150 meters thick is known. Zittel has recorded this limestone along the road from Assiut to Farafra. It is also known in Gebel Ataqa. In these two localities the typical snow-white limestones of this formation change in lithology so that other formational names may be necessary when a fuller study of the areal extent of this unit is made. The Minia limestone is now being studied in this laboratory.

Table 1 summarizes the classification presented in this paper.

THE THEBES FORMATION
Stratigraphy

The Gebel Gurnah section that lies in Thebes on the western side of the Nile facing Luxor, just behind the famous temple of Deir el-Bahari, commands a magnificent view of the world-renowned Pharaonic monuments of that city. This famous and accessible section is here chosen as the type locality of the open sea facies of lower Eocene (Ypresian) age. The section consists of limestones some 290 meters thick, here designated as the Thebes Formation. It overlies conformably the Esna Shale which is represented in this locality by some 55 meters of green laminated shales which have some marly intercalations in the upper part. The base of this shale is not exposed. The following is a section of this outcrop (see text-figure 1):

Top

Bed no.	Description	Thickness
1–	Yellow silicified limestone with *Gryphaea pharaonus*, *Ostrea multicostata* and *Nummulites subramondi*	30 m.
2–	Nummulitic limestone with *N. subramondi*	30 m.
3–	Limestone with abundant *Operculina libyca*, *Operculina* spp., *Nummulites praecursor* and various echinoids, *Heterospatangus lefebvrei*	35 m.
4–	Marl with scattered bands of flint concretions with abundant pelecypods, *Lucina thebaica*	75 m.
5–	White limestone with flint concretions with few macroscopic fossils	120 m.
6–	Esna shale with abundant limonitic fossils	55 m.

Base unexposed.

The limestone beds 1–5, inclusive, are here designated as the Thebes Formation and are believed to fall within the larger Lower Libya Group of Zittel.

The section was studied by Delanoue (1868) who gave a good description of it. Zittel (1883) assigned a Cretaceous age to the lower shale bed (Bed no. 6) and equated the top beds near Esna with his classic Gebel Der section of the "Unter Libysche Stufe" or early lower Eocene. This section is designated as "Gebel Ter bei Esna" by all paleontologists who worked on the materials of the Rohlf's Expedition, and also by Schaub (1951).

Cuvillier (1930) placed the lower shale bed in the Danian and the top limestone part in the upper Londinian. Nakkady (1950, 1951, 1957) described several samples from the Esna Shale of Luxor (Bed no. 6) with a fauna of sharply keeled Globorotalias. He assigned this unit to the "Danian to Paleocene" in 1950, 1951 and later changed the age to "upper Danian."

TABLE 1

OPEN SEA FACIES	TYPE LOCALITY	AGE	REEFAL FACIES	TYPE LOCALITY	AGE
			Minia Limestone	Minia	Lower Lutetian
Thebes Formation	Luxor	Ypresian	Farafra Limestone	Guss Abu Said	Ypresian
Esna Shale	Gebel Oweina	Landenian	Limestone members within this formation containing *Alveolina ovulum, Nummulites deserti,* and *N. fraasi.*		

Although Nakkady did not study the faunas of the upper limestone section, it is inferred from his diagrams that he considers the section to belong to the "Montian" since it includes his "*Operculina* Limestone" unit.

Nakkady (1951) recorded the following planktonic foraminifera from the Luxor Esna Shale: *Globorotalia colligera* var. *crassaformis, G. crassata* var. *aequa, G. deceptoria, G. simulatilis,* and *G. velascoensis.*

Youssef (1954) described the following species of planktonic foraminifera from the Esna Shale of Gebel Oweina, which lies about 60 kilometers south of Luxor: *Globorotalia colligera; G. simulatilis; G.* cf. *velascoensis; Globigerina bulloides* and *G. pseudotriloba.* He also recorded *Nummulites deserti, N. fraasi* and "other Nummulites" from beds occurring in this succession. He placed this Esna Shale bed in the lowermost Tertiary (Paleocene). No figures or systematic descriptions are given and no age is assigned to the 10–20 meter thick *Operculina* limestone bed that tops Gebel Oweina (= Thebes formation) which in his words "is generally attributed to the Eocene, but closer study may prove that this bed is still of Paleocene age." This same section is described by Nakkady (1958) with the following planktonics recorded from the Esna Shale: *Globigerina triloculinoides, G. pseudobulloides, Globorotalia angulata, G. simulatilis,* and *G. velascoensis.* The Esna Shale is assigned to the lower Paleocene or Montian (*s.l.*). The top *Operculina* limestone bed is assigned to the upper part of the lower Paleocene.

Paleontology

The present paper describes and illustrates the planktonic foraminifera of the Esna Shale formation in Luxor, and also the foraminifera of the Thebes Formation. The fauna from the Thebes Formation has not been described before. This paper makes use of the thorough studies of the planktonic foraminifera of the Cretaceous-Lower Tertiary deposits of the world (Loeblich and Tappan, 1957*a, b*; Bolli, 1957, Subbotina, 1953) in order to settle the question of the age of these controversial beds, and to illustrate and clarify the nomenclature of these important index fossils.

Because of their abundance, wide geographical distribution and rapid evolutionary development, planktonic foraminifera are ideal fossils for intercontinental geological zoning. The importance of these fossils has been stressed by many recent workers (Grimsdale, 1951; Loeblich and Tappan, 1957*a, b*; Bolli, 1957). This paper, which includes the systematic description of the planktonic foraminifera, admits as a basic principle the great value of these fossils. In spite of the author's belief in the value of planktonics in correlation studies, he (Said and Kenawy, 1956) has noted some discrepancies in the time distribution of these fossils, particularly in the flank section studied in Sinai. In this section the sharp-keeled Globorotalias seem to be late in appearing because of the influence of the processes of onlap and offlap. In presenting this explanation, which also was of use in solving many of the seemingly difficult problems in the sedimentation and paleontology of the Upper Cretaceous-Lower Tertiary successions of Egypt, the author emphasized what seemed to be an interesting discovery in such a way that it has given the impression that he does not consider the planktonics as valuable zone fossils. The mistake, made by the author in 1956, was pointed out by Loeblich and Tappan (1957*b*). The author now wishes to clarify the statement quoted by Loeblich and Tappan (1957*b*, p. 1122) so as to make it consistent with the thesis presented in that previous paper. In the Upper Cretaceous-Lower Tertiary sections that have been studied on the flanks of structural highs, the value of the planktonics in zoning is limited; since they occur in moderately deep water, their appearance is retarded in these sections. It must be emphasized that this statement does not by any means belittle the value of the planktonics as age indicators, because flank sections are quite limited in areal distribution.

Nakkady (1957) states that he observed the retardation of *Globorotalia* species in 1951 and that the present author noticed *this* retardation in 1956. He later makes this same statement in 1958. The author wishes now to affirm that the term 'retardation' used in the 1956 paper is totally different from Nakkady's use of the term. Whilst the author uses the word 'retardation' to denote the delay of appearance of *Globorotalia* species from the

time of their first appearance, Nakkady uses the word "delay" to indicate the time lag in the appearance of *Globorotalia* species from the well established *Globotruncana* surface. Nakkady (1957, p. 47) states that the "*Globorotalia* fauna of the sharply keeled type ... does not start right after the end of the *Globotruncana* zone, but is delayed for sometime and in some sections for a long lapse of time". If we take the literal meaning of Nakkady's statement, it would lead one to believe that sharply keeled Globorotalias are of no value whatsoever as time indicators because they are separated from the *Globotruncana* time reference surface by "sometime" in some sections and by "a long lapse of time" in others. If one carries this interpretation to its logical conclusion the sharply keeled Globorotalias cannot be taken as an index to the "Danian to Paleocene" (1951) or the "upper Danian" (1957, 1958) or any other age, as a matter of fact. But since Nakkady has consistently used the appearance of sharply keeled Globorotalias as time indicators, the present author interpreted the "delay" which Nakkady mentions in 1951 as denoting spacing rather than time.

PLANKTONIC FORAMINIFERA OF THE ESNA SHALE

The Esna Shale unit in the Luxor section is rich in planktonic foraminifera; especially in the upper marly layers where replaced limonitic planktonics make up a large part of the rock itself. The fauna included in these beds forms one unit. The followings pecies are recorded in this unit: *Globorotalia velascoensis, G. simulatilis, G. pseudotopilensis, G. interposita, G. pentacamerata, Globigerina triloculinoides, G. inaequispira* and *G. eocaena*. This fauna belongs to the zone of sharply keeled Globorotalias universally known and dated according to the most recent studies on the subject as upper Paleocene (Landenian). It can be correlated well with the *G. velascoensis* zone of Trinidad (Bolli, 1957) of Mexico (Velasco formation) or of the Gulf and Atlantic Coastal Plains, U.S.A. (Loeblich and Tappan, 1957a, b).

Subbotina (1953), in her detailed work on the zonation of the Tertiary succession of the USSR, places this unit in the Paleocene-lower Eocene. It is interesting to note that the *Globorotalia velascoensis* zone in the USSR contains, as in Egypt, *G. pentacamerata, G. pseudotopilensis* and *G. interposita*.

Nakkady classifies this assemblage as upper Danian (1957). Such an age assignment is hard to defend in the light of present information on the subject (Page 1957).

Although no nummulites have been noted in the Esna Shale succession of Luxor, Youssef (1954) noted the presence of *N. deserti* in the Landenian of Gebel Oweina. This form seems to be an index species for the Landenian of Egypt. It occurs in alternating and intercalating beds containing sharp-keeled Globorotalias. This fact has been observed by numerous authors, old and new (LeRoy, 1953). Many of the classical workers have noted the

TABLE 2

Bed no.	Sample no.	Globigerina eocaena	G. inaequispira	Globorotalia interposita	G. pentacamerata	G. pseudotopilensis	G. simulatilis	G. velascoensis	Globigerina triloculinoides	Hastigerina micra	H. aspera	Globorotalia conicotruncata	G. imitata	G. planoconica	G. thebaica
1	16										F			A	
3	15												F		
4	14										F	F		F	A
5	13											F		A	A
5	12								F					A	F
5	11								F				F	A	A
5	10							F	F				F	F	A
5	9								F					A	F
6	8				A	A	F	A							
6	7	F		F	A	A	R	A							
6	6		F	F	A	A	F	A	F						
6	5	F	F	F	A										
6	4	F	A	A			F	A	A						
6	3	F	A	F				A	A					A(?)	

A = abundant (more than 50 specimens);
F = frequent 10–50 specimens.

presence of *N. deserti* and *N. fraasi* in shales that later work has shown to contain sharp-keeled *Globorotalias* (see Hassan (1953) for Kharga, Youssef *et al.* (1953) for Qoseir). It is therefore obvious that *N. deserti* and *N. fraasi* are also good index fossils for the Landenian and can by no means be taken, as Nakkady believes (1957), as indicators of an horizon above the sharply keeled *Globorotalia* zone. They may represent a reefal facies in the Landenian.

PLANKTONIC FORAMINIFERA OF THE THEBES FORMATION

The limestone beds that overly the Esna Shale section in Luxor have a characteristic planktonic fauna with the following species: *Globorotalia planoconica, G. conicotruncata, G. thebaica, G. imitata, Hastigerina aspera, H. micra* and *Globigerina triloculinoides*.

The faunas from this formation have never been reported from Egypt. The abundance of *G. thebaica, G. imitata* and *G. planoconica* characterizes this zone. The age of this formation has been a subject of controversy for some time, but the microfauna of this formation indicates that it belongs to Subbotina's Paleocene-lower

Eocene unit. It may be of interest to point out here that the succession of *G. velascoensis* followed by *G. thebaica* is also noted in the USSR successions. In Egypt, however, the *G. thebaica* zone differs from the Russian zone in having more Paleocene-lower Eocene elements rather than lower Eocene-middle Eocene elements as is the case in the USSR.

It may also be of interest to note that the Nummulites in this section are quite localized in the succession but include *Nummulites subramondi* which is an index species of the lower Eocene of Egypt.

Table 2 gives the distribution of planktonic foraminifera described from the Luxor section.

SYSTEMATIC DESCRIPTIONS

Order FORAMINIFERA
Family HANTKENINIDAE Cushman
Genus HASTIGERINA Thomson

Hastigerina micra (Cole)
Plate 1, figure 13

Nonion micrus COLE, 1927, Bull. Amer. Pal., vol. 14, no. 51, p. 22, pl. 5, fig. 12.
Globigerinella micra (Cole). – SUBBOTINA, 1953, Vses. Neft. Nauchno.-Issled. Geol.-Razved. Inst. (VNIGRI), Trudy, new ser., vol. 76, p. 88, pl. 13, figs. 16–17.

Test small, planispirally coiled, almost totally involute; biumbilicate, periphery broadly rounded; chambers ovate, inflated, six to seven in the last whorl; sutures depressed, radial; wall very finely perforate; surface smooth; aperture interiomarginal, an elongate equatorial slit.

This is a small species that occurs frequently in the lowest part of the Thebes Formation (Bed no. 5). Specimens referred to this species differ from those figured by Subbotina (1953) in having their successive chambers increasing less rapidly in size. In the USSR this species is recorded from the lower to middle Eocene unit.

Hastigerina aspera (Ehrenberg)
Plate 1, figure 12

Phanerostomum asperum EHRENBERG, 1854, Mikrogeologie, pl. 30, fig. 26; pl. 32, fig. 42.
Globigerinella aspera (Ehrenberg). – SUBBOTINA, 1953, Vses. Neft. Nauchno. – Issled. Geol.-Razved. Inst. (VNIGRI), Trudy, new ser., vol. 76, p. 86, pl. 13, figs. 2–12.

Specimens that resemble those described by Subbotina are recorded from the upper beds of the Thebes Formation. This species resembles *Hastigerina micra* (Cole) but has a thicker wall, a more quadrate outline and a slightly more hispid appearance.

Family ORBULINIDAE Schultze
Genus GLOBIGERINA d'Orbigny

Globigerina eocaena Gümbel
Plate 1, figure 11

Globigerina eocaena GÜMBEL, 1868, Akad. Wiss., Abh., vol. 10, p. 662, pl. 2, fig. 109. – SUBBOTINA, 1953, Vses. Neft. Nauchno.-Issled. Geol.-Razved. Inst. (VNIGRI), Trudy, new ser., vol. 76, p. 70, pl. 6, fig. 5; pl. 7, fig. 1.

Test free, composed of gradually enlarging chambers in a low trochospiral arrangement; chambers subglobular, two whorls of chambers visible on the dorsal side, only four chambers of the final whorl visible on the umbilical side, chambers more or less the same in size; sutures distinct, depressed; wall calcareous, finely perforate; surface pitted; aperture interiomarginal, umbilical with a lip.

A large number of specimens is found in all Esna Shale samples and in the lower part of the Thebes Formation.

Globigerina inaequispira Subbotina
Plate 1, figure 10

Globigerina inaequispira SUBBOTINA, 1953, Vses. Neft. Nauchno.-Issled. Geol.-Razved. Inst. (VNIGRI), Trudy, new ser., vol. 76, p. 69, pl. 6, figs. 1–4. – LOEBLICH AND TAPPAN, 1957, U. S. Nat. Mus., Bull. 215, p. 181, pl. 49, fig. 2; pl. 52, figs. 1–2; pl. 56, fig. 7; pl. 61, fig. 3; pl. 62, fig. 2.

Test free, composed of rapidly enlarging chambers in a low trochospiral arrangement; chambers globular, only three to four chambers of the last whorl visible on the umbilical side; sutures distinct, depressed; wall calcareous, finely perforate, pitted; aperture interiomarginal, umbilical, may have a narrow lip.

A large number of typical specimens of this species is found in the Esna Shale samples.

Globigerina triloculinoides Plummer
Plate 1, figure 15

Globigerina triloculinoides Plummer. – LOEBLICH AND TAPPAN, 1957, U. S. Nat. Mus., Bull. 215, p. 183, pl. 40, fig. 4, pl. 41, fig. 2, pl. 42, fig. 2, pl. 43, figs. 5, 8–9, pl. 45, fig. 3, pl. 46, fig. 1, pl. 47, fig. 2, pl. 52, figs. 3–7; pl. 56, fig. 8, pl. 62, figs. 3–4.

Specimens found in the Esna Shale and the lower part of the Thebes Formation. All have a tripartite appearance on the umbilical side with an exceptionally large and inflated final chamber. Specimens differ from those recorded by Loeblich and Tappan from the Paleocene of the Gulf and Atlantic coasts, in the United States in having a finely pitted surface rather than a reticulate surface.

Family GLOBOROTALIIDAE Cushman
Genus GLOBOROTALIA Cushman

Globorotalia conicotruncata (Subbotina)
Plate 1, figure 7

Acarinina conicotruncata SUBBOTINA, 1953, Vses. Neft. Nauchno.-
Issled. Geol.-Razved. Inst. (VNIGRI), Trudy, new ser.,
vol. 76, p. 220, pl. 20, figs. 5, 6–12.

Specimens that resemble those recorded by Subbotina
are found in beds 4 and 5 of the Thebes Formation. This
species belongs to the smooth sharply keeled group in
which the test is a low trochospiral and the umbilicus
is shallow and wide.

Globorotalia imitata Subbotina
Plate 1, figure 5

Globorotalia imitata SUBBOTINA, 1953, Vses. Neft. Nauchno.-
Issled. Geol.-Razved. Inst. (VNIGRI), Trudy, new ser.,
vol. 76, p. 206, pl. 16, figs. 14–16. – LOEBLICH AND
TAPPAN, 1957, U. S. Nat. Mus., Bull. 215, p. 190, pl. 44,
fig. 3; pl. 45, fig. 6; pl. 54, figs. 8–9; pl. 59, fig. 5; pl. 63,
fig. 3.

Test small, spiral side flattened to gently convex, periph-
ery rounded, lobulate; chambers moderately inflated,
ovate, increasing gradually in size, arranged in a low
trochospiral coil of two volutions, four in the final
whorl; sutures depressed, gently curved; wall calcareous,
finely perforate; surface smooth; aperture extraum-
bilical-umbilical, a low slit bordered by a lip.

This species, originally described from the Danian
strata of the USSR, and later recorded from the
Landenian and lower Eocene strata of the Gulf and
Atlantic Coastal Plains in the U.S. is found throughout
the Thebes Formation.

Globorotalia interposita (Subbotina)
Plate 1, figure 9

Acarinina interposita SUBBOTINA, 1953, Vses. Neft. Nauchno.-
Issled. Geol.-Razved. Inst. (VNIGRI), Trudy, new ser.,
vol. 76, p. 231, pl. 23, figs. 6–7.

This small species is distinguished by having a quadrate
outline, inflated chambers arranged in a low trocho-
spiral coil with four chambers in the final whorl. It
differs from *G. imitata* Subbotina in having a more
pitted surface and a more rounded peripheral margin.
It differs from *G. pseudotopilensis* (Subbotina) in having
a more rounded periphery, and in having a shallower
and narrower umbilicus.

Numerous specimens that belong to this species are
found in all Esna Shale samples.

Globorotalia pentacamerata (Subbotina)
Plate 1, figure 4

Acarinina pentacamerata SUBBOTINA, 1953, Vses. Neft. Nauchno.-
Issled. Geol.-Razved. Inst. (VNIGRI), Trudy, new ser.,
vol. 76, p. 233, pl. 23, fig. 8, pl. 24, figs. 1–9.

This is a distinctive species which is found in abundance
throughout the Esna Shale. This species is characterized
by having a rounded peripheral margin and by having
five more or less equal chambers in the final whorl.

Globorotalia planoconica Subbotina
Plate 1, figures 8, 14

Globorotalia planoconica SUBBOTINA, 1953, Vses. Neft. Nauchno.-
Issled. Geol.-Razved. Inst. (VNIGRI), Trudy, new ser.,
vol. 76, p. 210, pl. 17, figs. 4–6.

This is a small species with a very low trochospiral coil
and a flattened spiral side, a smooth surface with six to
seven chambers in the final whorl. This species is found
in abundance throughout the Thebes Formation. Similar
specimens that may belong to this species are also found
in the lower Esna Shale sample. These specimens are
larger, have inflated chambers, depressed sutures and
more rounded periphery. These specimens may be
similar to *Anomalina luxorensis* Nakkady.

Globorotalia pseudotopilensis (Subbotina)
Plate 1, figure 3

Acarinina pseudotopilensis SUBBOTINA, 1953, Vses. Neft. Nauchno,
Issled. Geol.-Razved. Inst. (VNIGRI), Trudy, new ser.,
vol. 76, p. 227, pl. 21, figs. 8–9; pl. 22, figs. 1–3.
Globorotalia pseudotopilensis (Subbotina). – LOEBLICH AND
TAPPAN, 1957, U. S. Nat. Mus., Bull. 215, p. 194, pl. 60,
fig. 2.

Test inflated, periphery subtruncate, peripheral outline
lobulate, with a final chamber broadest somewhat above
its base presenting a trapezoidal appearance; chambers
four in the last whorl; wall calcareous, finely hispid;
aperture interiomarginal, extraumbilical.

This species is distinguished by the shape of its final
chamber which rises abruptly and precipitously above
the deep and distinct umbilicus. Specimens agree in
detail to those figured by Subbotina except for the
finely hispid surface.

This species is found in great numbers throughout the
Esna Shale, Luxor.

Globorotalia simulatilis (Schwager)
Plate 1, figure 1

Discorbina simulatilis SCHWAGER, 1883, Palaeontographica,
vol. 30, p. 120, pl. 29, fig. 15.

Shape of test a low trochospiral; spiral side slightly
convex; equatorial periphery weakly lobulate; axial
periphery acute; chambers angular, slightly inflated,
arranged in $2\frac{1}{2}$ to 3 coils, five to six in the last coil,
increasing gradually in size as added; sutures on spiral
side strongly curved, slightly limbate, on umbilical side,
radial, strongly depressed; umbilicus, narrow, shallow;
aperture a narrow slit, interiomarginal, extraumbilical-
umbilical.

A study of the topotype material of Schwager's species figured from El Guss Abu Said leads me to believe that LeRoy's *G. simulatilis* (1953, p. 32, pl. 9, figs. 1–3) cannot be assigned to this species. This species is distinguished by its acute axial periphery, shallow umbilicus, convex spiral side and by its raised and strongly curved spiral sutures. Numerous specimens of this species are found in the Esna Shale samples from Luxor.

Globorotalia thebaica Said, new species
Plate 1, figure 6

Test small, spiral side flattened; periphery subrounded; chambers moderately inflated, increasing gradually in size as added, ovate, arranged in a low trochospiral coil of two whorls; four to five chambers in the final whorl; wall calcareous, finely perforate; surface smooth; umbilicus shallow and small; aperture extraumbilical with a lip.

This species is quite similar to *G. whitei* Weiss, except for the shape of the spiral sutures and the surface ornamentation. *G. crassaformis* (Galloway and Wissler) of Subbotina (1953) may belong here.

A large number of specimens of this species are found throughout the Thebes Formation and this species may be of zonal value when more sections of the Ypresian are studied.

Globorotalia velascoensis (Cushman)
Plate 1, figure 2

Pulvinulina velascoensis Cushman, 1925, Cushman Lab. Foram. Res., Contr., vol. 1, pt. 1, p. 19, pl. 3, fig. 5.
Globorotalia velascoensis (Cushman). – LeRoy, 1953, Geol. Soc. Amer., Mem. 54, p. 33, pl. 3, figs. 1–3.

Specimens identified as belonging to this species are very similar to *G. simulatilis* (Schwager) in general shape. They differ, however, by having an ornate axial periphery, a wider umbilicus, less curved spiral sutures and more volutions on the spiral side. This species is found in great numbers in all Esna Shale samples.

PLATE 1

In all figures, a: spiral view; b: side view; c: umbilical view. All figures × 50.

1   *Globorotalia simulatilis* (Schwager)
From sample no. 3

2   *Globoratalia velascoensis* (Cushman)
From sample no. 3

3   *Globoratalia pseudotopilensis* (Subbotina)
From sample no. 3

4   *Globoratalia pentacamerata* (Subbotina)
From sample no. 3

5   *Globoratalia imitata* Subbotina
From sample no. 10

6   *Globoratalia thebaica* Said, n. sp.
Holotype, from sample no. 10

7   *Globoratalia conicotruncata* (Subbotina)
From sample no. 14

8, 14   *Globoratalia planoconica* Subbotina
Fig. 8 from sample no. 16; fig. 14 from sample no. 4

9   *Globoratalia interposita* (Subbotina)
From sample no. 7

10   *Globigerina inaequispira* Subbotina
From sample no. 4

11   *Globigerina eocaena* Gümbel
From sample no. 5

12   *Hastigerina aspera* (Ehrenberg)
From sample no. 14

13   *Hastigerina micra* (Cole)
From sample no. 12

15   *Globigerina triloculinoides* Plummer
From sample no. 3
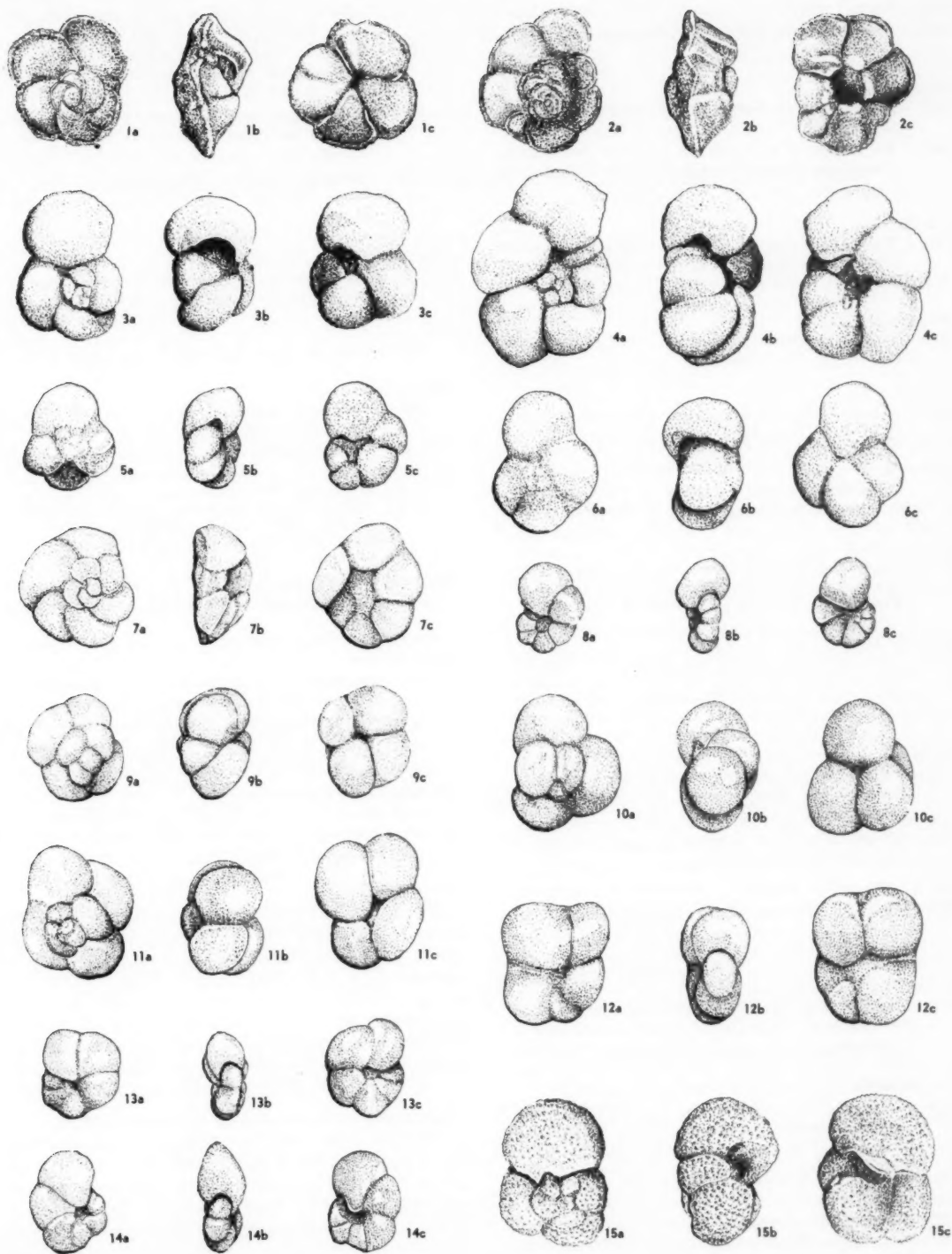
BIBLIOGRAPHY

BALL, J.
1900 – *Kharga Oasis. Its Topography and Geology.* Surv. Dept., Cairo.

BEADNELL, H. J. L.
1901 – *Farafra Oasis. Its Topography and Geology.* Surv. Dept., Cairo.

1905 – *The relations of the Eocene and Cretaceous systems in the Esna-Aswan Reach of the Nile Valley.* Geol. Soc. London, Quart. Jour., vol. 61, pp. 667–678.

BOLLI, H. M.
1957 – *The genera Globigerina and Globorotalia in the Paleocene-Lower Eocene Lizard Springs formation of Trinidad, B.W.I.* U. S. Nat. Mus., Bull. 215, pp. 61–82.

CUVILLIER, J.
1930 – *Revision du Nummulitique egyptien.* Inst. Égypte, Mem., vol. 16, pp. 1–371, pls. 1–25.

DELANOUE, J.
1868 – *Note sur la Constitution géologique des environs de Thebes.* C. R. Acad. Sci., Paris, vol. 67, pp. 701–707.

FOURTAU, R.
1902 – *Contribution a l'étude Géologique de l'Isthme de Suez.* C. R. Assoc. Av. Sci., vol. 31, pp. 486–488.

GRIMSDALE, T. F.
1951 – *Correlation, age determination, and the Tertiary pelagic foraminifera.* World Petr. Congr., III (The Hague), Proc., sec. 1, pp. 463–475, 1 text-fig.

HASSAN, M. Y.
1953 – *The occurrence of Nummulites deserti de la Harpe in Kharga Oasis and the age of the lower Libyan in southern Egypt.* Inst. Désert, d'Égypt, Bull., vol. 3, no. 2, pp. 114–122, 1 pl.

HUME, W. F.
1911 – *The effects of Secular oscillation in Egypt during the Cretaceous and Eocene periods.* Geol. Soc. London, Quart. Jour., vol. 67, pp. 118–148.

1912 – *Explanatory notes to accompany the geological map of Egypt.* Surv. Dept., Cairo.

LeRoy, L. W.
1953 – *Biostratigraphy of the Maqfi section, Egypt.* Geol. Soc. Amer., Mem., no. 54, pp. 1–73, pls. 1–14, text-figs. 1–4, table 1.

LOEBLICH, A. R., AND TAPPAN, H.
1957a *Planktonic foraminifera of Paleocene and early Eocene age from the Gulf and Atlantic Coastal plains. Studies in foraminifera; Part I – Planktonic foraminifera.* U. S. Nat. Mus., Bull., no. 215, pp. 173–197, pls. 40–64, text-figs. 27–28.

1957b *Correlation of the Gulf and Atlantic Coastal Plain Paleocene and lower Eocene formations by means of planktonic foraminifera.* Jour. Pal., vol. 31, no. 6, pp. 1109–1137, text-figs. 1–5.

NAKKADY, S. E.
1949 – *The foraminiferal fauna of the Esna shales of Egypt.* Inst. Egypte, Bull., vol. 31 (1948–1949), pp. 209–247, text-figs. 1–8, 1 table.

1950 – *A new foraminiferal fauna from the Esna shales and Upper Cretaceous chalk of Egypt.* Jour. Pal., vol. 24, no. 6, pp. 675–692, pls. 89–90, text-figs. 1–4.

1951 – *Zoning the Mesozoic-Cenozoic transition of Egypt by the Globorotaliidae.* Univ. Alexandria, Fac. Sci., Bull., no. 1, pp. 45–58.

1957 – *Biostratigraphy and inter-regional correlation of the upper Senonian and lower Paleocene of Egypt.* Jour. Pal., vol. 31, no. 2, pp. 428–447, text-figs. 1–3, table 1.

1958 – *Stratigraphic and Petroleum Geology of Egypt.* Univ. Assiut, Monogr., ser. no. 1, pp. 1–211, 37 text-figs., maps.

OSMAN, A.
1954 – *Upper Cretaceous foraminifera of western Sinai.* Cairo Univ., Fac. Eng., Bull., pp. 335–365, pls. 1–5, map.

PAGE, R. A.
1957 – *Discussion.* Jour. Pal., vol. 31, no. 6, pp. 1176–1177.

REICHEL, M.
1936 – *Étude sur les Alvéolines.* Schweiz. Pal. Ges., Abh. (Soc. Pal. Suisse, Mém.), vol. 57, pp. 1–93, pls. 1–9, text-figs. 1–16.

SAID, R., AND KENAWY, A.
1956 – *Upper Cretaceous and Lower Tertiary foraminifera from northern Sinai.* Micropaleontology, vol. 2, no. 2, pp. 105–173, pls. 1–7, text-figs. 1–6.

SAID, R., AND KERDANY, M.
[MS] – *The stratigraphy and micropaleontology of the Farafra Oasis.*

SCHAUB, H.
1951 – *Stratigraphie und Paläontologie des Schlierenflysches mit besonderer Berücksichtigung der paleocaenen und untereocaenen Nummuliten und Assilinen.* Schweiz. Pal., Abh. (Soc. Pal. Suisse, Mém.), vol. 68, pp. 1–222, pls. 1–9, text-figs. 1–336, table 1.

STRATIGRAPHIC COMMISSION
1956 – *Report 4. Nature, Usage, and Nomenclature of Rock Stratigraphic units.* Amer. Assoc. Petrol. Geol., Bull., vol. 40, pp. 2003–2014.

SUBBOTINA, N. N.
1953 – *Fossil foraminifera of the U.S.S.R., Globigerinidae, Hantkeninidae and Globorotaliidae.* Vses. Neft. Naukno-Issled. Geol. Razved. Inst. (VNIGRI), Trudy, n. ser., no. 76, pp. 1–296, pls. 41, text-figs. 1–8, tables 1–3.

YOUSSEF, M. I.
1954 – *Stratigraphy of the Gebel Oweina section, near Esna, Upper Egypt.* Inst. Desert, d'Egypte, Bull., vol. 4, no. 2, pp. 83–93, pls. 1–2.

YOUSSEF, M. I., HASSAN, M. Y., AND ABDU, H. F.
1953 – *A faunule with Nummulites deserti from Kosseir area.* Inst. Desert, d'Egypte, Bull., vol. 3, no. 2, pp. 123–124.

ZITTEL, K. A.
1883 – *Beiträge zur Geologie und Paläontologie der Libyschen Wüste und der angrenzenden Gebiete von Aegypten.* Paläontographica, vol. 30, pt. 1, p. 83.

ABSTRACT: *A new genus,* Rimosocella, *is proposed for cheilostome bryozoa described by Canu and Bassler (1920) as* Quadricellaria? laciniosa. *Study of topotypes from the Castle Hayne marl (Eocene) of North Carolina and additional material from the McBean formation (Eocene) of Georgia has disclosed the necessity for complete redescription and illustration of the species.*

Rimosocella, new genus of cheilostome Bryozoa

ALAN CHEETHAM
Louisiana State University
Baton Rouge, Louisiana

INTRODUCTION

Zoarial form was the chief criterion for separating genera of cheilostome bryozoa a hundred years ago (d'Orbigny, 1851; Busk, 1859). Subsequent research by Smitt (1867), Hincks (1880), and later workers has proved that colonial growth form varies among congeneric species, even within some species, and that distantly related bryozoans often assume similar zoarial structure through adaptive convergence.

Cheilostomata having articulate zoaria composed of calcareous internodes joined together by chitinous threads were originally assigned to the genus *Cellaria.* Soon after 1850 many cellariiform genera, both fossil and living, were proposed on the basis of form and arrangement of zooecia, type of ovicell, and presence of accessory structures such as avicularia and vibracularia. These genera include *Nellia, Poricellaria, Quadricellaria, Scrupocellaria, Tetraplaria, Tubucellaria,* and others which belong to divergent stocks but which have become similar in zoarial structure through adaptation to life in shallow, strongly agitated water.

Quadricellaria was described by d'Orbigny (1851) from Senonian rocks in France and has since been recorded from other European Cretaceous localities (Voigt, 1930). The only "quadricellarias" that have been reported from post-Cretaceous rocks are two Eocene species described by Canu and Bassler (1920) from the Castle Hayne marl at Wilmington, North Carolina. These were provisionally assigned by their authors to *Quadricellaria,* on the basis of zoarial form.

Canu and Bassler had at hand only a few specimens of these species, *Q.? laciniosa* and *Q.? burnsi.* Additional samples from the Castle Hayne and one from the McBean formation of northeastern Georgia, all deposited in the Louisiana State University Geology Museum, have yielded many more specimens, including several topotypes, of *Q.? laciniosa.* Study of this material, including one ovicelled internode, had disclosed the

necessity for complete redescription and reillustration of the species and introduction of a new genus to receive it.

This genus, *Rimosocella,* differs considerably from *Quadricellaria* (compare text-figs. 1 and 3). *Rimosocella* displays ovicells, vibracularia, and opesiulae, all of which are lacking in *Quadricellaria.* Moreover, the opesia and cryptocyst are of different form in the two genera.

Assignment of *Rimosocella* to the proper family is a matter of some difficulty because of its unique structure, but the presence of endozooecial ovicells and opesiulae makes it likely that this genus belongs with the Microporidae. Among the microporid genera, *Monsella* Canu, from the Paleocene of Belgium, resembles *Rimosocella* in possessing articulate zoarium and vibracularia but lacks multiple, slitlike opesiulae; *Nematoporella* Canu and Bassler, from the Miocene of France, has multiple opesiulae and vibracularia, but the opesiulae are not slit-like. *Rimosocella* seems to form a link between the ovicelled microporids and the non-ovicelled calpensiids, especially *Discoporella* d'Orbigny (Miocene to Recent) which has multiple, slit-like opesiulae and vibracularia.

SYSTEMATIC DESCRIPTION

Order CHEILOSTOMATA Busk
Suborder ANASCA Levinsen
Family MICROPORIDAE Hincks

Genus **Rimosocella** Cheetham, **new genus**

Type species: Quadricellaria? laciniosa Canu and Bassler, 1920.

Diagnosis: Microporidae having complete cryptocyst with multiple, paired, slit-like opesiulae; adventitious vibracularia; endozooecial ovicells; and (at least in the type species) delicate, articulate zoaria with zooecia arranged in alternating series on all four faces.

This genus differs from *Nematoporella* Canu and Bassler in possessing slit-like opesiulae and from *Monsella* Canu in having multiple opesiulae.

Rimosocella is known only from its type species which occurs in Eocene rocks in North Carolina and Georgia.

The name of the genus is derived from *rimosus*, full of chinks or clefts, and *cella*, a small compartment.

Rimosocella laciniosa (Canu and Bassler)
Text-figures 2–5

Quadricellaria? laciniosa CANU AND BASSLER, 1920, U. S. Nat. Mus., Bull. 106, p. 279, pl. 40, figs. 18–20.

Material: Topotype no. 7073, Castle Hayne marl, Wilmington, North Carolina; specimen no. 7074, Castle Hayne marl, quarry on dirt road 0.7 mile west of Carlton, North Carolina; specimen no. 7075, McBean formation, 0.4 mile east of highway bridge over McBean Creek, Richmond County, Georgia. The figured specimens are catalogued in the type collection of the Louisiana State University Geology Museum; additional specimens from these localities were studied but not catalogued.

Original description: "The zoarium is articulated, with segments quadrangular; each face bears on each zooecium a large *slit* in the form of a crescent. The zooecia are quite elongate, distinct, formed of two parts. A shallow, very finely punctate cryptocyst and an inferior triangular gymnocyst. The aperture is semilunar and surrounded by a prominent peristome; the proximal border is straight with two small lateral slits. The ovicell is endotoichal."

Redescription: Zoarium erect, jointed; internodes slender, straight or curved, square in cross section, composed of four rows of zooecia, one on each face; zooecia on adjacent faces alternate in position. Sixteen zooecia observed in largest internode fragment. Articulating ends of internodes blunt, tapering, equipped with a pair of radicular pores.

Zooecia elongate claviform, rounded distally, bluntly tapering proximally, about one-sixth to one-fourth as wide as long. Gymnocyst smooth, flat to gently arched transversely extending one-tenth to one-half zooecial length from proximal margin. Mural rim smooth, salient, flat to rounded frontally.

Cryptocyst flat, uniformly depressed below mural rim, occupying proximal three-fourths of area enclosed by mural rim. Lateral margins each with eight to 17 slit-like opesiulae; mature zooecia with two additional submedian rows of seven to nine slit-like pores each; pores of submedian rows alternate in position with opesiulae.

Opesiae semicircular to semielliptical, rounded distally, straight proximally. Lateral and distal margins formed by continuation of mural rim sloping distally. Proximo-lateral corners with rudimentary tubercles. Proximal lip slightly lower than mural rim.

Vibracularia small, asymmetrical, adventitious, one pair projecting distolaterally from gymnocyst of each zooecium toward opesia of laterally adjacent zooecium.

Ovicells small, smooth, little salient, endozooecial, partly separated from zooecial interior by reduced distal margin of opesia. Covering of ovicell formed by arching of gymnocyst of distally adjacent zooecium. Labellum evenly rounded.

Measurements	Number	Mean mm.	S.D.* mm.	Range mm.
Zooecial length (Lz)	10	0.508	0.288	0.34–1.11
Zooecial width (lz)	10	0.166	0.040	0.11–0.23
Opesial length (ho)	8	0.052	0.014	0.05–0.06
Opesial width (lo)	7	0.073	0.032	0.06–0.09

*Standard Deviation

Discussion: The large crescentic "slits" mentioned in the original description probably refer to the proximal part of the mural rim, i.e., the contact between the cryptocyst and the gymnocyst. The latter feature is quite variable in its development; the specimens illustrated by Canu and Bassler display the same amount of variability as those upon which the redescription is based. Seemingly, this variability is at least partly ontogenetic, zooecia from young zoaria (text-fig. 2) having much longer gymnocysts than those from mature zoaria (text-figs. 3–5).

With regard to the cryptocyst, the original description is not only inadequate but also misleading. The slit-like opesiulae and pores are not even mentioned, although they are discernible on at least one of Canu and Bassler's figures (pl. 40, fig. 18). Moreover, the fine punctations that are mentioned in the description seem to have been produced by retouching the photograph (pl. 40, fig. 19).

Variation in number and arrangement of cryptocystal slits also seems to be related to ontogeny. Zooecia from young zoaria (text-fig. 2) have twice as many opesiulae as those from mature zoaria (text-figs. 3–5), but they lack submedian pores such as those that alternate in position with the opesiulae of older zoaria. It seems likely, therefore, that half of the opesiulae in a young zooecium remain stationary at the margins of the cryptocyst while alternate ones migrate toward the zooecial midline with growth.

The small lateral slits (opesiular indentations?) mentioned in the original description as occurring on the proximal border of the opesia are not displayed either in the new material or in Canu and Bassler's figures.

Canu and Bassler described the ovicell of this species as endotoichal, i.e., a separate chamber with its orifice removed from the zooecial opesia, yet their figures illustrate no ovicelled zooecia. The new material in-
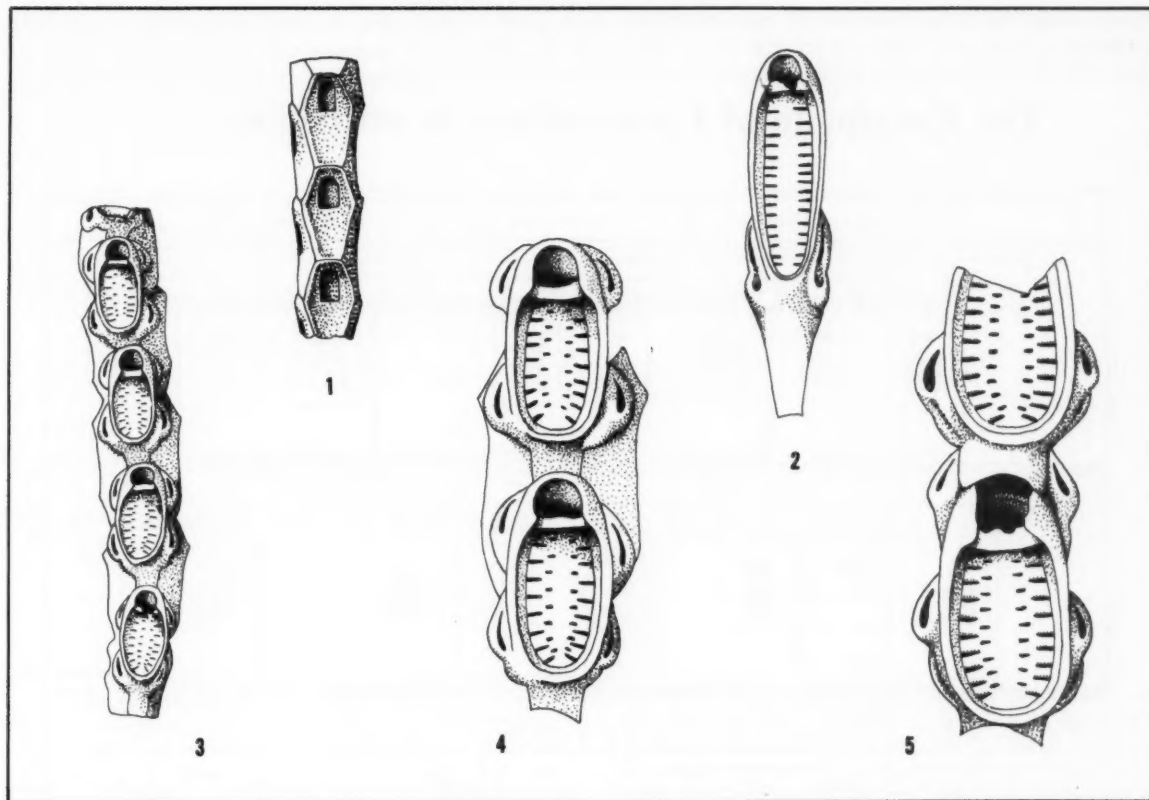
TEXT-FIGURES 1–5

1, *Quadricellaria elegans* d'Orbigny, type species of *Quadricellaria*, fragment of an internode, × 50 (after d'Orbigny, 1851). 2–5, *Rimosocella laciniosa* (Canu and Bassler). 2, topotype no. 7073, normal zooecium and two vibracularia from a young zoarium, × 100; 3, specimen no. 7075, mature internode fragment, × 50; 4, specimen no. 7075, four normal zooecia and eight vibracularia, × 100; 5, specimen no. 7074, ovicelled zooecium, part of distally adjacent zooecium, and six vibracularia, × 100.

cludes a single ovicelled internode (text-fig. 5), and the ovicells are clearly endozooecial, i.e., enclosed in the distal part of the mother zooecium.

No mention is made in the original description of vibracularia, although they are prominently displayed by the specimens illustrated (Canu and Bassler, 1920, pl. 40, figs. 18–20).

REFERENCES

BUSK, G.
  1859 – *A monograph of the fossil Polyzoa of the Crag.* Paleontogr. Soc., Mon., London, p. 1–136, pls. 1–22.

CANU, F., AND BASSLER, R. S.
  1920 – *North American early Tertiary Bryozoa.* U. S. Nat. Mus., Bull. 106, 869 pp., 161 pls.

HINCKS, T.
  1880 – *A history of the British marine Polyzoa.* London, van Voorst, 601 pp., 83 pls.

D'ORBIGNY, A.
  1851 – *Paléontologie francaise. Terrains crétacés, tome 5, Bryozoaires.* Paris, Masson, 1192 pp., pls. 600–800.

SMITT, F. A.
  1867 – *Kritisk forteckning ofver Skandinaviens Hafs-Bryozoer.* Ofver. K. Vet.-Akad., Forhandl., Stockholm, vol. 23, pp. 395–533, pls. 3–13.

VOIGT, E.
  1930 – *Morphologische und stratigraphische Untersuchungen über die Bryozoenfauna der oberen Kreide.* Leopoldina, vol. 5, pp. 379–579, 39 pls.

The Catalogue of Foraminifera in microfilm

Aboudaragina Nakkady, 1955 — Actinocyclina aster Woodring, 1930
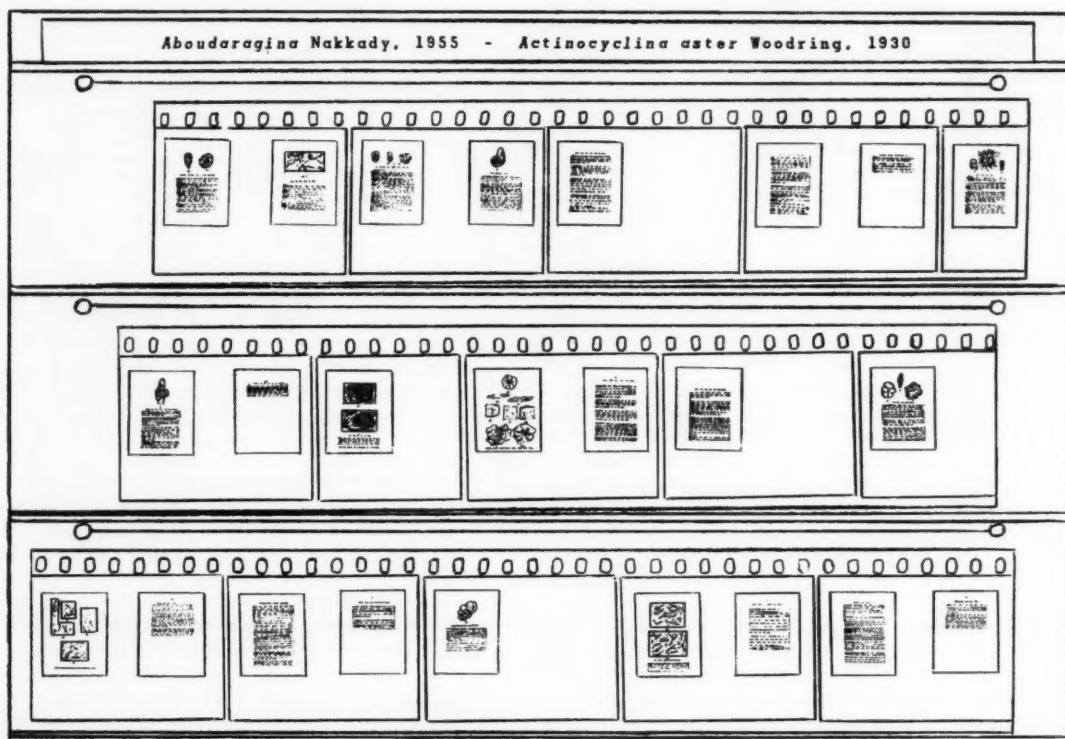
TEXT-FIGURE 1

The printed edition of the Catalogue of Foraminifera was exhausted in 1958. A new printing cannot be undertaken because of the great cost. The demand for the Catalogue continues, however, and a microfilm edition has been prepared to meet this demand.

The microfilm edition consists of thirty-three 100 foot rolls of 35 mm. film on which the Catalogue, complete through 1958, has been reproduced. More than 1580 genera and 25,275 species are included in this edition.

The rolls of film can be used as issued or cut into strips of four or five frames each and filed in transparent plastic holders (text-figure 1) supplied with each microfilm copy of the Catalogue. These holders can accommodate a total of fifteen frames each, and each frame can be viewed individually in a special flat-bed viewer. Space in which to file supplementary frames can be provided by not filling the holders to capacity initially.

Supplements to the microfilm edition are issued annually and consist of a roll of 35 mm. film. If the transparent holders are being used for the original copy, the supplements should be cut into individual frames and interfiled in the proper places to maintain the alphabetic arrangement. The supplementary frames can be interspliced in the original rolls if a conventional type reader is to be used.

The Catalogue, filed in the transparent holders, can be accommodated in four 5 × 8 × 24 inch file drawers. Self-adhering labelling strips are also supplied with the plastic holders.

This microfilm edition of the Catalogue of Foraminifera is now available on a subscribing membership basis. Inquiries and applications should be directed to the Department of Micropaleontology, The American Museum of Natural History, Central Park West at 79th Street, New York, N. Y. THE EDITORS.

ABSTRACT: *Acid residues from limestone obtained from a single locality in eastern Nevada have yielded five lagenid species of Triassic foraminifera. The specimens are silicified and are present in over 600 feet of section. The fauna is associated with Lower Triassic conodonts and occurs about 1000 feet above the Lower Triassic (Scythic) ammonoid guide*, Meekoceras.

Lower Triassic foraminifera from Nevada

W. W. SCHELL AND DAVID L. CLARK
*Sun Oil Company
Richardson, Texas*, and
*Brigham Young University
Provo, Utah*

INTRODUCTION

After the extinction of the fusulinids in the late Permian, the foraminifera seem to have played a relatively unimportant role in invertebrate faunas until the Upper Jurassic and Cretaceous. In spite of the fact that Triassic (Middle and Upper) foraminifera have been known for some time in Europe (Bornemann, 1885; Mariani, 1893), the only published account in North America concerns an Upper Triassic fauna from Alaska (Tappan, 1951). Although there were probably small numbers of Triassic foraminifera, their apparent scarcity in the North American Triassic is also due partly to the fact that marine rocks of this age are not widespread and also because of the fact that little detailed paleontologic work has been done. Foraminifera were secured from Triassic rocks sampled in the eastern Great Basin during the summers of 1955 and 1956. The fauna is small, but its Lower Triassic age makes it significant. The samples were collected while the junior author was with the Shell Oil Company, Ely, Nevada. The Sun Oil Company has graciously granted the senior author permission to publish this paper. The manuscript and photographs were prepared at the Sun Oil Company Research Laboratory and at Southern Methodist University, Dallas, Texas.

STRATIGRAPHY

Foraminifera have been obtained from only one of the nearly 30 different Triassic localities that were sampled in the western Utah–eastern Nevada area. Their absence in sections with the same lithology and associated fauna may indicate unusual conditions of preservation at the single locality, some 14 miles north of Currie, Nevada, on the east side of Spruce Mountain (T. 30 N.,

R. 64 E.). A detailed description of this Triassic occurrence has been published (Clark, 1957, section P). The section consists of some 3000 feet of bioclastic limestones and shales. The foraminifera were found in three different samples in a stratigraphic interval of 600 feet. Samples from bed P–13, which is about 1000 feet above the base of the Triassic, have yielded the largest number and variety. The recorded distribution is summarized in text-figure 1. The foraminifera-bearing beds are coarse grained bioclastic limestones interbedded with unfossiliferous shales. Some 108 specimens, representing five lagenid species, were obtained in association with conodonts and echinoderm fragments. The limestones were treated with 1:7 glacial acetic acid and the foraminifera were caught on a 100 mesh screen. As these species of foraminifera have not been established as time significant, the age determination for the fauna is based on the stratigraphically associated ammonoids and conodonts. The foraminifera occur about 1000 feet above the *Meekoceras* zone of Lower Triassic (Scythic) age. Conodonts found in association with the foraminifera are the same species which are common in the *Meekoceras* and lower beds, e.g. *Ellisonia triassica* Müller and *Neoprioniodus bransoni* Müller. The range of these conodont species has been published (Clark, 1959). Nothing other than what appears to be Lower Triassic fossils has been reported in the 2000 feet of section above the foraminiferal beds, and, on the basis of the ammonoids and conodonts, the foraminifera are considered to be of Lower Triassic age.

All specimens are deposited in the micropaleontological collection, Brigham Young University.

Spruce Mountain Section

Occurrence of Foraminifera

1. *Lingulina* aff. *L. dentalinaformis* (Terquem)
   L. triangulata n. sp.
2. *Marginulina* ? sp.
3. *Nodosaria collenoti* (Terquem)
4. *Pseudofrondicularia triassica* n. sp.
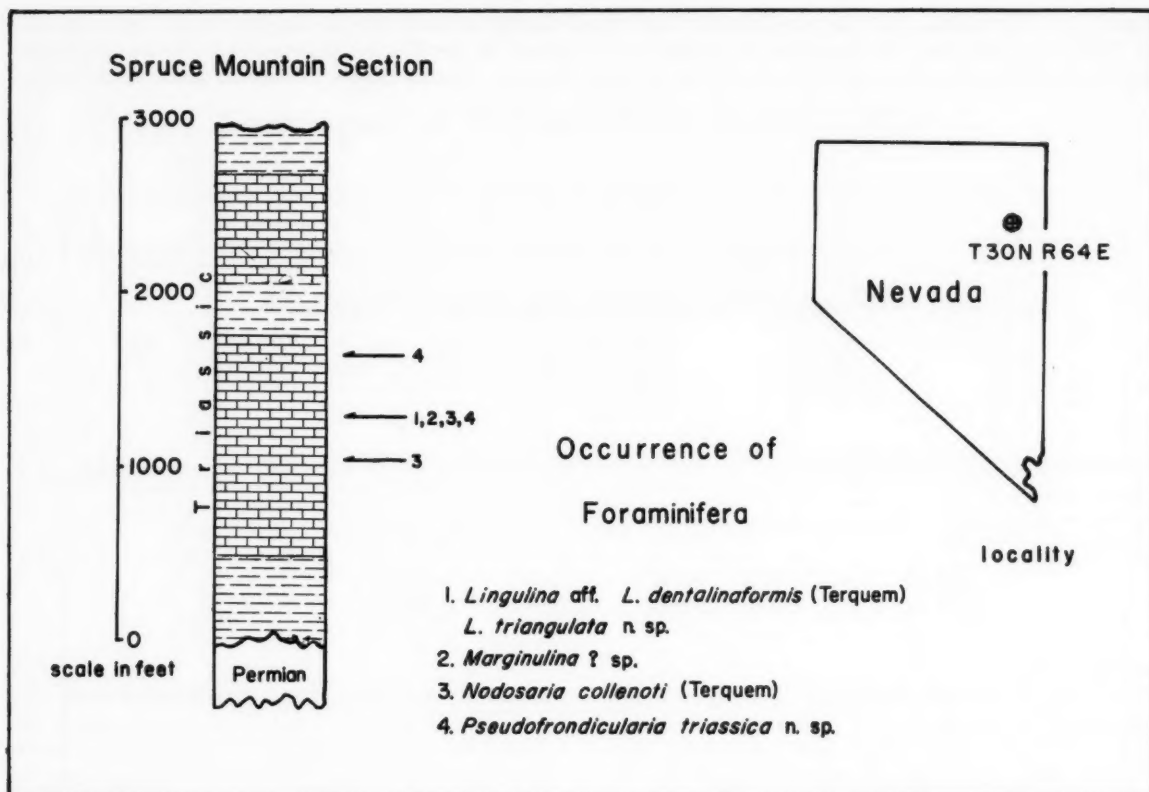
TEXT-FIGURE 1
Locality and stratigraphic distribution of Lower Triassic foraminifera.

Order FORAMINIFERA
Family LAGENIDAE
Genus NODOSARIA Lamarck, 1812

Nodosaria collenoti (Terquem)
Plate 1, figures 7–8, 13–14, 20–22, 27

Dentalina collenoti TERQUEM, 1864, Acad. Imp. Metz., vol. 44, p. 176, pl. 7, fig. 15.

Test up to .8 mm. in length, varying from 3.8 to 6.4 times the maximum diameter. Straight to slightly curved, tapering rather gradually but not constantly in all specimens; circular in section normal to the principal axis of growth, periphery lobate; chambers subspherical to ellipsoidal to pyriform, usually distinct, occasionally the earlier ones obscure, inflated, increasingly so toward the apertural end. In the juvenile stages (first and second chambers) the diameter is twice the height, the adult stage shows diameter equal or the height may be 1.2 to 1.3 times the diameter, final chamber is 1.5 times as high as the maximum diameter at this stage. The greatest diameter is at or very near the middle of each chamber excepting in the final one, which has its greatest lateral dimension considerably below the middle, forming an attenuate chamber which, in some cases, produces a pyriform shape; each chamber overlaps the preceding one by about one-third its length. Proloculus spherical to subcylindrical, attenuate apically, sharpened but without a well-developed spine, the height and greatest diameter equal, or the height up to 1.35 times the greatest diameter. Sutures usually distinct, except for the earlier ones, and flush to very slightly depressed in the early stages, becoming increasingly depressed in the adult; straight, at right angles to the long axis of the test. Aperture a simple circular opening at the distal end of the final chamber; wall relatively thin, sucrose, formed from minute quartz crystals, some as large as .15 mm. long and doubly terminated. Specimens, which are replicas, appear as morphologically distinctive drusy masses of quartz, steinkerns, smooth and dense, with an occasional large crystal adhering to the specimen.

Remarks: Perhaps the most striking aspect of these specimens is the euhedral quartz crystals which appear on the surface of the tests. The exact manner of for-

mation, whether they developed in the void created by solution of the rock and original test or in some other way, is not clear.

The forms here described differ from the types in the nature of the proloculus and the constancy of chamber shape. Terquem (1864) described the first chamber as rounded, the others as of uniform shape, and the last as sharpened. His figures do not confirm this consistency, although they are somewhat more constant than the specimens from Nevada. The variation in prolocular shape is so common among the lagenids that further discussion is unwarranted.

Types: Brigham Young University, nos. 508, 509.

Genus LINGULINA d'Orbigny, 1826

Lingulina sp. aff. L. dentaliniformis (Terquem)
Plate 1, figures 23–24

Frondicularia dentaliniformis TERQUEM, 1870, Acad. Imp. Metz., Mem., p. 217, pl. 23, figs. 1–8. – JONES, 1876, Jour. Roy. Soc. London, vol. 15, pl. 128, fig. 27. – BARTENSTEIN AND BRAND, 1937, Senckenb. Naturf. Ges., Abh., no. 439, p. 153, pl. 10, fig. 22, p. 109.

Test .475 mm. long, four times the maximum width, gently tapering, flattened, elliptical in section normal to the long axis, periphery labiate, sharpened but not keeled. Chambers distinct, inflated, uniserially arranged, increasing markedly in height as added. In the young stages with the width greater than the height, the ultimate and penultimate chambers with height exceeding the width. Proloculus flattened, posteriorly apiculate; sutures distinct, depressed, straight. Wall relatively smooth, consisting of minute quartz crystals; aperture terminal, a narrowly elliptical opening. Length of figured specimen .475 mm.; maximum width .125 mm.; thickness .075 mm.

Remarks: Our collections contain only two specimens of this species, and since this taxon exhibits a wide range of characteristics the identification is questionable.

Type: Brigham Young University, nos. 502, 510.

Lingulina triangulata Schell and Clark, new species
Plate 1, figures 1–6, 9–12, 17

Test up to .525 mm. in length, four to seven times the maximum width, tapering rapidly in the initial portion, much less so in the adult, in some specimens with sides parallel. Compressed, elliptical in section normal to the principal axis of growth, periphery pagodal, rounded. Chambers distinct, uniserially arranged, slightly inflated, thickest in the central portion below the middle, generally the first two or three increasing in width rather rapidly, subsequent increase less marked or absent. Chambers overlap from one-eighth to one-third of the previous chamber with the consequent height/width ratios quite variable, triangular to subtriangular in shape, the sides forming an anterior angle averaging between 15 and 45 degrees per specimen.

The base is flat or very nearly so in the juvenaria, becoming arched in the adult, concave posteriorly. Basal angles sharpened but not spinose; proloculus spherical or with a posteriorly directed attenuation; sutures distinct, very slightly depressed and straight in the young stages, becoming strongly depressed and curved in the adult. Aperture terminal, central, a small round or slightly elongate opening at the apex of the triangular chamber. Wall of the replicas thin, sucrose, consisting of randomly oriented minute quartz crystals. Steinkerns smooth and dense with an occasional large euhedral quartz crystal emanating from the specimen. Length of holotype is .400 mm., maximum width .08 mm., maximum thickness .05 mm.

Remarks: This species is most similar to *L. serrata* Tappan. It differs in the lack of a subcarinate periphery, anteriorly directed maximum chamber thickness, and produced spines at the basal angles of the chambers. The sucrose wall of our specimens is also to be contrasted with the smooth exterior of *L. serrata*.

Type: Brigham Young University, nos. 500, 506, 507.

Genus MARGINULINA d'Orbigny, 1826

Marginulina? sp.
Plate 1, figures 15–16

We have one fragmentary specimen which might be assigned to one of several lagenid genera. The gently sigmoidal ventral and lobed dorsal margins suggest affinities with *Marginulina*. The test is ovate in cross-section and the sutures are depressed and slope back at approximately 35 degrees from a point just inside the dorsal margin. This latter feature is one more commonly found in vaginuline and cytharine species. The aperture, although broken in our specimen, is undoubtedly terminal and located at or near the dorsal margin. The wall, like that in other species of this assemblage, is sucrose, consisting of minute randomly arrange quartz crystals. Length of figured specimen .425 mm.; maximum width .125 mm.; maximum thickness .080 mm.

Type: Brigham Young University, no. 501.

Genus PSEUDOFRONDICULARIA Wedekind, 1937

Pseudofrondicularia triassica Schell and Clark, new species
Plate 1, figures 18–19, 25–26

Test up to .45 mm. in length, up to three times the maximum width, tapering at angles of 10 to 16 degrees, averaging 12 degrees. In some specimens the initial end tapers rapidly with the ensuing portion having sides nearly parallel. Maximum thickness of test .07 mm. and medially furrowed, the periphery narrowly rounded, only slightly lobed. Chambers distinct, uniserially arranged, very slightly inflated, chevron-shaped, the sides forming an anterior angle which varies among

individuals from 66 to 96 degrees, increasing very gradually in height as added, the width two and one-fourth to three and one-fourth times the height. The posteriorly directed "wings" extend back over the lateral margins to a point in line with the base of the preceding chamber, and produce an overlap value varying from .03 to .05 mm., generally thickest in the center of the "wings". Sutures distinct, slightly depressed, straight or very slightly concave upward, rarely convex, forming angles of 30 to 50 degrees with the median axis of the test, and averaging 42 degrees. Aperture is a simple circular opening at the distal end of a short neck which, in some cases, flares to a distinct collar; wall of replicas thin, sucrose, consisting of minute, randomly oriented quartz crystals, the steinkerns smooth and dense. Length of holotype .450 mm.; maximum width .150 mm.; thickness .070 mm.

Remarks: This species may be distinguished from *P. biformis* (Marsson) by its greater anterior chamber and suture angles, depressed, non-limbate sutures, and the presence of a median furrow. *P. carinata* var. *longa* (Issler) has an entire periphery which, in the early stages of development, is carinate. *P. dubari* (Morrow) has a greater chamber overlap and a distinctly smaller chamber angle.

Types: Brigham Young University, nos. 503, 504, 505.

BIBLIOGRAPHY

BORNEMANN, J. G.
1885 – *Beiträge zur Kenntniss des Muschelkalks, insbesondere der Schichtenfolge und der Gesteine des Unteren Muschelkalks in Thüringen.* K. Preuss. Geol. Landesanst. und Bergakad. Jahrb., vol. 6, pp. 267–321, pls. 7–14.

CLARK, D. L.
1957 – *Marine Triassic stratigraphy in eastern Great Basin.* Amer. Assoc. Petrol. Geol., Bull., vol. 41, pp. 2192–2222.
1959 – *Conodonts from the Triassic of Nevada and Utah.* Jour. Pal., vol. 33, no. 2, pp. 305–312, 2 pls., 1 text-fig.

MARIANI, E.
1893 – *Note paleontologiche sul trias superiore della Carnia occidentale.* R. Inst. Tec. A. Zanon Udine, Ann., ser. 2, Ann. 11, pp. 13–35, 3 pls.

TAPPAN, H.
1951 – *Foraminifera from the Arctic slope of Alaska.* U. S. Geol. Survey, Prof. Paper, no. 236–A, pp. 1–20, pls. 1–5, text-figs. 1–2.

TERQUEM, M. O.
1864 – *Troisieme mémoir sur les foraminifères du Lias des départments de la moselle, de la Côte-d'or, du Rhone, de la Vienne et du Calvados.* Acad. Imp. Metz, Mém., vol. 44 (ser. 2, vol. 11), pp. 361–438, pls. 7–10.

PLATE 1

All illustrations, except figure 20, are stereophotomicrographs; × 53.

1–6, 9–12, 17   *Lingulina triangulata* Schell and Clark, n. sp.
1–6, 11, 12, paratypes, B. Y. U. 506; 17, paratype, B. Y. U. 507; 9, 10, holotype, B. Y. U. 500; 1, 3, 5, 9, 11, 17, lateral views; 2, 4, 6, 10, 12, apertural views.

7–8, 13–14,   *Nodosaria–collenoti* (Terquem)

20–22, 27   20, holotype, after Terquem (1864); 7, 13, 21, 27, lateral views; 8, 14, 22, apertural views; hypotypes, B. Y. U. 508.

15–16   *Marginulina?* sp.
Lateral and apertural views, B. Y. U. 501.

18–19, 25–26   *Pseudofrondicularia triassica* Schell and Clark, n. sp.
18, 19, paratype, lateral and apertural views, B. Y. U. 504; 25, 26, holotype, lateral and apertural views, B. Y. U. 503.

23–24   *Lingulina* sp. aff. *dentaliniformis* (Terquem)
Apertural and lateral views, B. Y. U. 502.

PLATE 1
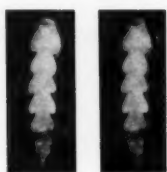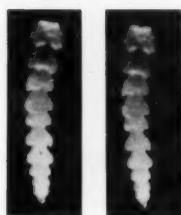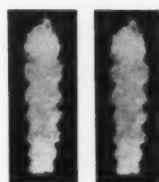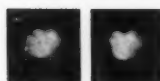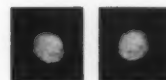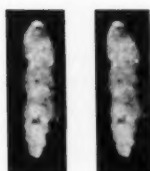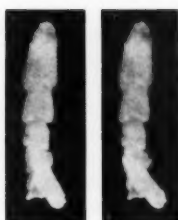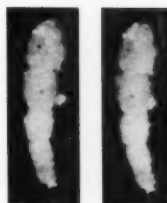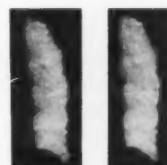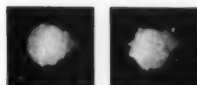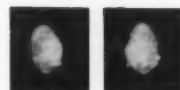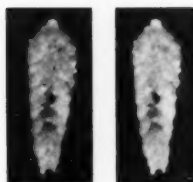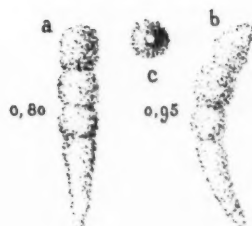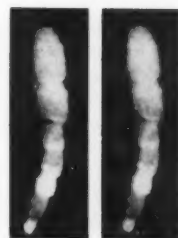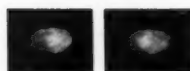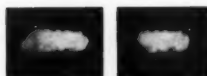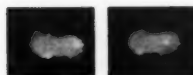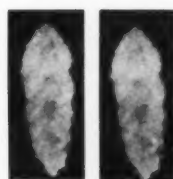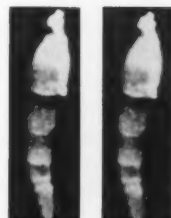
ABSTRACT: *Seven trace elements – manganese, titanium, aluminum, magnesium, strontium, copper and nickel – were examined in the tests of planktonic foraminifera in cores from the Atlantic Ocean. Manganese concentrations appear to be related to geographic location; copper is probably stable in planktonic foraminiferal tests.*

Trace elements in the tests of planktonic foraminifera

DAVID KRINSLEY
Queens College
Flushing, New York

INTRODUCTION

Planktonic foraminiferal tests from deep sea cores were examined to determine if their trace element composition varied according to geographic location. Recently Emiliani (1955) analyzed the tests of certain planktonic foraminifera from deep sea cores for trace elements and mineralogical composition. He found as did Blackmon and Todd (1959) that these tests were made of calcite. This eliminated the problem of varying mineralogical composition which could affect trace element uptake. Emiliani also found that the abundance of trace elements characteristic of terrigenous deposits in the tests of planktonic foraminifera generally appeared to be greater in Atlantic than in Pacific samples. He suggested that this was either because the Pacific samples washed more cleanly, or because these elements were less abundant in the Pacific than in the Atlantic. If the latter is true, this fact may be related to the drainage density of the two oceans. Revelle, *et al.* (1955) indicate that only 24 rivers exceeding 400 kilometers in length empty into the Pacific while the corresponding number of rivers emptying into the Atlantic is more than 100.

The following are ways in which addition or loss of trace elements in shell material might occur before deposition:

1) Trace element uptake may be related to the amount of a particular element in the aqueous medium; that is, the animal may concentrate an element in direct proportion to the amount in the medium at a given time. This has been shown by Odum (1950) for strontium in the shells of certain fresh water gastropods.

2) The animal may concentrate a particular element for some physiochemical or physiological reason which may not be directly related to the amount of the element in sea water. It has been shown that the temperature of the sea water in which shell deposition occurs may affect the mineralogy of that shell, which in turn affects trace element uptake (Lowenstam, 1954, with respect to aragonite percentages and strontium).

However, since all foraminifera examined in this study were composed of calcite, the problem did not arise here. Chave (1954) found that magnesium concentrations were related to temperature in planktonic foraminiferal tests, but Blackmon and Todd (1959) were unable to find such an effect.

It has been suggested by Turekian (1955) that the strontium content of the shells of certain organisms is related to the salinity of the water in which they were secreted. Because salinity differences in the open ocean are very slight this possibility seems remote in planktonic foraminiferal shells.

3) The element may be concentrated because its chemical and physical properties are similar to those of other elements which the organism uses physiologically (McCance and Masters, 1937; Fretter, 1953). For instance, strontium may take the place of calcium in aragonitic shells.

After deposition and/or burial on the ocean bottom the following changes in addition to the above might occur:

1) Goldberg (1954) has shown that certain ions may be adsorbed (scavenged) by hydrated ions of manganese and iron; this process could take place on the surface of shell material. Organic matter arising from the waste products or death of organisms could cause deposition of metallic ions on shells prior to deposition on the sea floor. Thus scavenging could occur during life or after death at any time prior to or after deposition, assuming the right set of conditions. This may be one of the major reasons for variability of trace elements in the shells of modern animals. These points could be checked by experimentation.

2) In some cases, sediment contamination may affect analyses of trace elements in shell material (Emiliani, 1955), although it may be theoretically possible to remove all of the contaminant by washing.

3) Finally all diagenetic effects (heat, solution, etc.) may be grouped together; the effect of these factors individually is largely unknown (Krinsley, 1956), but they undoubtedly become intensified with increasing age and depth of burial.

The problem, then, is to chemically analyze shell material and relate composition to the proper factor or factors causing uptake or loss of trace elements. It can be seen from the above discussion that this is a complex problem, but it is also apparent that a good starting point would be the analysis of modern material. Physiological studies with radioactive tracers such as have been made by Fretter (1953) represent a beginning. However, it is possible to obtain information from the analysis of fossil material if the above points are taken into consideration.

It is theoretically possible that a foraminiferal species might concentrate a particular trace element in its shell material to a different extent than do other species, although this has never been observed. This phenomenon may be evaluated by analyzing the same species from different cores, as well as different species and "total foraminifera" (all species of planktonic foraminifera in a single core combined) from the same core. If different species from the same core have the same trace element composition but differ from other cores taken at different geographic localities, then differences from core to core are probably not due to a species effect.

If this is the case, then the amount of a particular trace element found in tests of the same species in cores from different locations may be related to the concentrations of that element in the ocean at a given locality and to the various processes which cause accumulation in and on shell material.

METHOD

The author had available planktonic foraminifera from the tops of five deep-sea cores taken by the Lamont Geological Observatory's ship *Vema* from different parts of the Atlantic Ocean (Table 1). Spectrographic analyses were made on *Globigerinoides rubra* (d'Orbigny), *Globigerina inflata* d'Orbigny, *Globorotalia truncatulinoides* (d'Orbigny) and "total planktonic foraminifera" (Table 2); without exception all specimens were taken from tops of cores. These samples probably represent the most recent sediments, although the elapsed time since deposition is unknown.

Samples were washed in distilled water and representative portions were sorted for individual species. They were then crushed between glass slides and washed again in an agitator for one hour, and dried in an oven at 100° C. Upon examination under a binocular microscope, it was found that an extremely small amount of extraneous or foreign material still adhered to the shell fragments. No method of completely removing all of this material was found.

TABLE 1

CORE NUMBER	LOCATION
(1) R5–54	25° 52′ N., 19° 03′ W. – southwest of Tenerife, Canary Islands
(2) A180–44	18° 32½′ N., 17° 23′ W. – off Cape Verde, Africa
(3) A164–44	33° 57′ N., 62° 39′ W. – near Bermuda
(4) A181–TW7	10° 33′ N., 57° 20′ W. – off mouth of Orinoco River
(5) A180–TW15	39° 16′ N., 36° 42′ W. – off Azores

All specimens were removed from tops of cores.

The shells were analyzed spectrochemically in the geochemistry laboratory of Lamont Geological Observatory according to the method reported by Bieri and Krinsley (1959), with modifications. The analyses were accurate to $\pm 15\%$ of the determined values. Table 2 lists the various elements analyzed and arranged so that the concentrations at each locality can be easily seen.

RESULTS

The problem of sediment contamination of the fine shell fragments after washing must be considered. Emiliani (1955) believed that titanium, aluminum and magnesium were probably contained in this fraction while strontium and manganese were not, and that small amounts of manganese might be associated with the foraminiferal shell material (present in the calcite structure). However, abundant manganese is present in pelagic clay: Clarke (1924) reported 0.765% of this element in a composite mixture of 51 samples. Abundant concentrations of manganese have been reported in deep-sea cores (Revelle, *et al.*, 1955). Krinsley and Bieri (1959) have shown that increase in manganese in pteropod shells in some cases takes place after deposition on the sea floor. Post-depositional increases in manganese have probably also taken place in foraminiferal tests in the present study, although a very small percentage may have been taken into the structure during life of the organisms. Manganese seems to be relatively stable with respect to a particular geographic location. Concentrations in "total foraminifera" are about the same as in species analyzed individually (Table 2). The amount of manganese may be related to the concentration of the element in the water at a particular time and locale and to the degree to which the element might be scavenged by other compounds. Finally, manganese is more stable in all planktonic foraminiferal tests at a given locality than any of the other elements reported here.

Emiliani (1955) has suggested that magnesium is not associated with shell material; he has plotted percentages of aluminum (probably land derived) against magnesium and found that the two elements are covariant. This suggests sedimentary contamination; however the

TABLE 2

SPECTROGRAPHIC ANALYSES – % BY WEIGHT					
	Caribbean A181–TW7	Azores A180–TW15	Bermuda A164–44	Cape Verde A180–44	Canary Islands R5–54
MnO					
G. rubra	.0012				.0017
G. inflata		.0082	.0041	.0072	.0023
G. truncatulinoides					.0016
Total foraminifera	.0015		.0040		.0015
TiO$_2$					
G. rubra	.031				.058
G. inflata		.063	.040	.070	.058
G. truncatulinoides					.058
Total foraminifera	.060		.038		.036
Al$_2$O$_3$					
G. rubra	.60				.32
G. inflata		.51	.43	.64	.37
G. truncatulinoides					.34
Total foraminifera			.31		.27
MgO					
G. rubra	.34				.24
G. inflata		.37	.17	.41	.17
G. truncatulinoides					.24
Total foraminifera	.25		.27		.30
SrO					
G. rubra	.13				.13
G. inflata		.20	.15	.12	.12
G. truncatulinoides					.21
Total foraminifera	.11		.13		.12
CuO					
G. rubra	.0010				.0020
G. inflata		.0012	.0010	.0010	.0010
G. truncatulinoides					.0011
Total foraminifera	.0038		.0010		.0010
NiO					
G. rubra	.002				.003
G. inflata		.003			
G. truncatulinoides					.002
Total foraminifera					

magnesium in the contaminant is probably superimposed on magnesium in the carbonate shell structure. This is the case with respect to the data in this paper. Magnesium appears to have some relationship to locality, but this is not as obvious as in the case of manganese.

It has been noted that magnesium is mobile in calcium carbonate (Zeller and Wray, 1956) and tends to move both in and out of shell material with time (Krinsley, 1956). Krinsley and Bieri (1959) have shown that some pteropod shells apparently free of all extraneous material have increased in magnesium content as the result of remaining for a relatively short time on the Mediterranean sea bottom. Blackmon and Todd (1959) have analyzed a number of specimens representing several genera of foraminifera taken from bottom sediments; their analyses are not as detailed as those in this paper and therefore they did not need to consider the possibility of magnesium movement. However the fresh appearance of shells and lack of recrystallization is no indication of stability (Krinsley, 1956; Krinsley and Bieri, 1959).

Because little data is available it is necessary to examine the literature on copper in the shells of organisms other than foraminifera. It may then be possible to relate this information to copper concentrations in the planktonic foraminifera discussed here.

Copper in pteropod shells of different species taken in net tows ranged from <.0008% to .0020% by weight,

a relatively narrow range assuming that the former figure was close to .0008% (Krinsley and Bieri, 1959). Copper analyses of pteropod shells taken from two cores fall within this range except for one species which has a considerably greater amount of copper (.010%). This suggests that the latter figure is primarily due to either contamination from the surrounding sediments or more probably to hydrogenous copper; Revelle, *et al.* (1955) report both hydrogenous and biogenous copper in the ocean.

Copper in the modern shells of *Tegula funebralis* (A. Adams), a littoral gastropod found on the western coast of North America, ranged from .0028% to .011% by weight of copper (12 specimens) in shells of varying aragonite content (see Krinsley, 1959 for data on aragonite content of this species). Two analyses of Pleistocene specimens, unrecrystallized, showed .010% and .0045% copper by weight. A Pliocene specimen, completely recrystallized (100% calcite) contained .0050% copper by weight. Note that all fossils fall within the modern range. These shells were carefully hand cleaned and little possibility of sedimentary contamination existed. The above information indicates that copper is probably stable in this species with time and that concentrations of copper beyond modern ranges suggest a non-biogenous component. It would be interesting to determine the phylogenetic level at which a copper difference first appears; the data available suggests that there is such an effect.

The copper range in the planktonic foraminifera studied in this paper is quite limited (.0010% to .0012% CuO) except for two analyses (.0020% and .0038%); it is suggested that the copper in the former figure is biogenic while the latter is a mixture of both biogenic and non-biogenic copper. It seems probable that copper is relatively stable in planktonic foraminiferal tests; netted specimens should be analyzed to confirm this point.

Titanium and aluminum are not as stable as manganese with respect to a single locality; strontium apparently has no relationship to locality (Table 2). Titanium and aluminum probably originated from land-derived sediments (Emiliani, 1955). Strontium is not a sedimentary contaminant; it is included in the carbonate structure and is fairly stable with time unless recrystallization has occurred (Odum, 1950; Krinsley, 1956). Nothing at present can be said about nickel as too few analyses have been made.

SUMMARY

Manganese concentrations in planktonic foraminiferal tests seem to be related to location and probably time. Copper, on the other hand, appears to be relatively constant with respect to geographic location; no species effect is apparent. Sedimentary magnesium is probably superimposed on biogenic magnesium in planktonic foraminiferal tests. Strontium is relatively stable from one core to another and is biogenic. Aluminum and titanium are probably sediment contaminents; little information is available for nickel.

BIBLIOGRAPHY

BIERI, R., AND KRINSLEY, D.
1958 – *Trace elements in the pelagic coelenterate Velella lata.* Jour. Marine Res., vol. 16, no. 3, pp. 246–254.

BLACKMON, P. D., AND TODD, R.
1959 – *Mineralogy of some foraminifera as related to their classification and ecology.* Jour. Pal., vol. 33, no. 1, pp. 1–15.

CHAVE, K. E.
1954 – *Aspects of the biogeochemistry of magnesium. I – Calcareous marine organisms.* Jour. Geol., vol. 62, pp. 266–283.

CLARKE, F. W.
1924 – *Data of geochemistry.* U. S. Geol. Survey, Bull. 770.

EMILIANI, C.
1955 – *Mineralogy and chemical composition of the tests of certain pelagic foraminifera.* Micropaleontology, vol. 1, no. 4, pp. 377–380, text-figs. 1–3, tables 1–4.

FRETTER, V.
1953 – *Experiments with radioactive strontium in certain mollusks and polychaetes.* Marine Biol. Assoc. U. K., Jour., vol. 32, pp. 367–384.

GOLDBERG, E.
1954 – *Marine Geochemistry. I – Chemical scavengers of the sea.* Jour. Geol., vol. 62, pp. 249–265.

KRINSLEY, D.
1956 – *Mineralogical and trace element composition of modern and fossil shell material.* [Univ. Chicago, unpubl. Ph. D. dissertation.]
1959 – *Manganese in modern and fossil gastropod shells.* Nature, vol. 183, pp. 770–771.

KRINSLEY, D., AND BIERI, R.
1959 – *Changes in the chemical composition of pteropod shells after deposition on the sea floor.* Jour. Pal., vol. 33, no. 4, pp. 682–684.

LOWENSTAM, H. A.
1954 – *Environmental relations of modification compositions of certain carbonate secreting marine invertebrates.* Nat. Acad. Sci., Proc., vol. 40, pp. 39–48.

McCANCE, R. A., AND MASTERS, M.
1937 – *The chemical composition and the acid base balance of Archidoris britannica.* Marine Biol. Assoc. U. K., Jour., vol. 22, pp. 273–278.

ODUM, H. T.
1950 – *Biogeochemistry of strontium.* [Yale Univ., unpubl. Ph. D. dissertation.]

REVELLE, R., BRAMLETTE, G., ARRHENIUS, G., AND GOLDBERG, E. D.
1955 – *Pelagic sediments of the Pacific.* Geol. Soc. Amer., Spec. Paper, no. 62, pp. 221–236, text-figs. 1–11.

TUREKIAN, K.
1955 – *Paleoecological significance of the strontium-calcium ratio in fossils and sediments.* Geol. Soc. Amer., Bull., vol. 66, pp. 155–158.

ZELLER, E. J., AND WRAY, J. L.
1956 – *Factors influencing precipitation of calcium carbonate.* Amer. Assoc. Petrol. Geol., Bull., vol. 40, pp. 140–152.

ABSTRACT: *Only bedded limestones and marls and bioherms of sponges are to be found in the deposits of the northern border of Oxfordian Tethys. Among the 132 species of foraminifera occurring here, 31 are characteristic of the bedded facies, and 14 of the sponge environment. These are restricted to the direct neighborhood of the sponge bioherms. Moreover, the carbonate content has some influence on the microfauna. These facts indicate the scarcity of bottom currents.*

Foraminifera in sponge bioherms and bedded limestones of the Malm, south Germany

EUGEN AND ILSE SEIBOLD
Kiel University
Kiel, Germany

INTRODUCTION

The difficulty in using foraminifera for stratigraphical and paleoecological purposes is well known. This difficulty arises mainly with the benthonic forms, because of their sensitivity to environment. This environmental influence on the microfauna is very complex and difficult to detect.

We have tried to study this problem by choosing an ideal case, *viz.* the Oxfordian and lower Kimmeridgian (Upper Jurassic) of south Germany. During this period, shelf sediments rich in lime were deposited between the ancient central European continent and the Jurassic Mediterranean Sea known as the Tethys. The sediments consist almost exclusively of bedded microcrystalline limestones containing no coarse material.

The extremely regular bedding in this succession persists over many kilometers in horizontal extent. Two profiles which have been taken in a distance of approximately 30 kilometers, show the same varying percentage of lime. This varying percentage of lime caused the bedding, which was not altered by bottom currents or diagenesis.

At some places, these bedded limestones carry intercalations of sponges which, in Germany, are designated as "Schwammriffe" (sponge bioherms) (text-figs. 5, 9, 12). These siliceous sponges usually occur in marls, but obviously developed better in water without clay sediments.

We took about 220 samples from the bedded marls and limestones and from the sponge bioherms over a distance of 300 kilometers. The limestones were etched in order to recover the siliceous foraminifera. The marls were treated with sodium sulfate after which they were washed in the usual way. For further details please see Seibold and Seibold (1960) in the "Neues Jahrbuch für Geologie und Paläontologie."

INFLUENCE OF THE FACIES
Occurrence in bedded marls

It was noted that there are species of foraminifera which occur only in the bedded series and others which prefer the spongy facies. For example, *Dentalina oppeli* (text-fig. 1) is represented in the bedded series in two samples by 11 to 25 specimens, and in eight samples by 6 to 10 specimens. An additional eight samples contained 3 to 5 specimens, and 24 samples had 1 to 2 specimens. On the other hand, there were only 5 occurrences of 1 to 2 specimens each of this form in the spongy facies.

Lenticulina (Astacolus) comptula is less sharply restricted in distribution (text-fig. 2). The reverse is true in the case of *Nodosaria raphanistriformis* (text-fig. 3). This form is restricted almost entirely to the spongy facies.

The results of this analysis indicate that in 86 of the more abundant species of foraminifera, 31 species prefer a bedded facies, and 14 choose a spongy facies. The remaining 41 species are unrestricted.

A selection of the most important representatives is shown in text-fig. 4. There are genera whose species are present in the limestone and marl beds and others in the sponge environment (*Ammobaculites* etc. as shown in the text-figure). It is apparent that foraminifera of a smaller size and often conical in shape occur more abundantly near sponges or even in the sponges themselves. However, the most characteristic feature of the foraminifera occurring in the spongy facies is their great uniformity.

Occurrence in sponges

This great uniformity is even more evident in the 50 etched sponges. Again, with a single exception, the same 16 species of foraminifera are always found in this facies. This applies to all horizons and also to all types of sponges. The fact that these foraminifera were
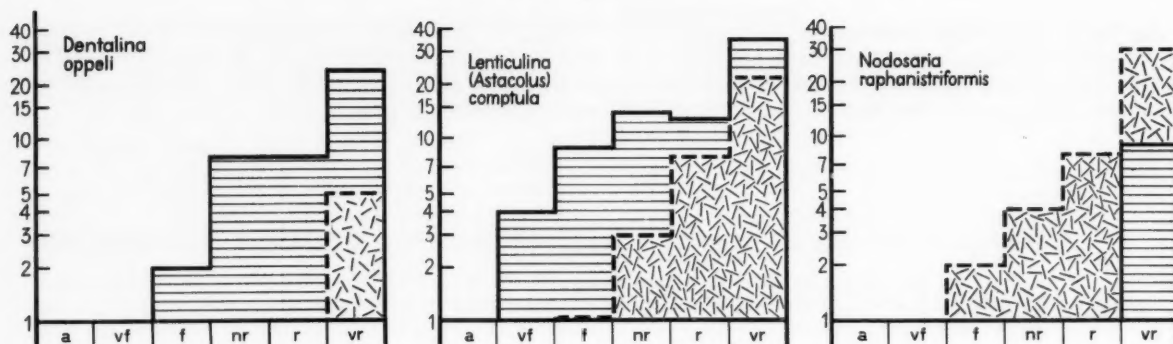
Examples of sensitiveness to facies. Occurrence of different species of foraminifera in samples taken from bedded marls (horizontal lines) and sponge marls (dashed lines). The number of samples is marked on the ordinate in logarithmic scale, the abscissa gives the different accumulations. Abundant (a) over 50 specimens per sample; very frequent (vf) 26–50; frequent (f) 11–25; not rare (nr) 6–10; rare (r) 3–5; very rare (vr) 1–2.

living in the sponges can be shown in some cases. The deformation of the test of *Thurammina gracilis* indicates that it grew around sponge spicules (text-figs. 6, 7). *Tolypammina* sp., for example, was found *in situ* within a pore canal of an etched sponge (text-fig. 8).

Lime content

As indicated above, only the varying lime content determines the facies of the bedded sections. This has had its effect also on the foraminifera. It is not surprising that, with a rising content of lime, the number of species, as well as individuals, generally decreases.

Brotzenia parastelligera (text-fig. 11) occurs abundantly only in those beds where the lime content is under 60 percent. The contrary can also be true. Some species obviously prefer beds with a high percentage of lime. *Haplophragmium coprolithiformis sequanum* occurs most abundantly in beds with 70–80 percent of $CaCO_3$ (text-fig. 10). Twelve of the more frequent species of the foraminifera studied occur in samples with a low percentage of lime and 4 in samples with a higher lime content. In summary, it can be stated that 16 species (19%) are sensitive to lime. (Seibold and Seibold, 1959).

CONCLUSIONS
Stratigraphy

Taking into account the foraminifera that are sensitive to different facies and which are affected, either by the bedded or the spongy surroundings, or by the lime content, there remain only 28 of the more abundant species, that is about a third, which are indifferent to surroundings. Only these could be of good stratigraphic value. However, they cannot be used to determine the age of these beds because they occur in all horizons investigated. The exception to this rule is *Frondicularia*

moelleri angusta Seibold and Seibold (1960) which occurs more abundantly (text-fig. 4). Among the 132 species of foraminifera investigated, only the latter species is of stratigraphic value.

Bottom currents

As mentioned above, the occurrence of some foraminifera indicates a close connection with the percentage of lime in the sediments. Many species occur only in beds poor in lime, while others occur only in beds rich in lime. The size of some varies according to the lime content. This relationship shows that neither the microfauna nor the extremely fine-grained sediments have been greatly displaced. Therefore, strong bottom currents did not exist.

This conclusion is substantiated when the total fauna is considered. Those foraminifera that occur with sponges hardly ever occur in the same sample with foraminifera that lived in a lime environment.

Of the 185 marl samples investigated, 169 samples contain only foraminifera of sponge marl facies or, on the other hand, only foraminifera of bedded marls. Only sixteen samples contain representatives of both groups of foraminifera. These samples might indicate strong current action whereas the major part reflect an environment where there was slight current action.

From the viewpoint of topography, the sponge microfauna tends to occur in the immediate neighborhood of sponge bioherms. This tendency is demonstrated in an example from the eastern Schwaebische Alb where, at some places, the small sponge bioherms occur right beside bedded limestones (text-figs. 5, 12).

Foraminifera associated with sponges are sharply restricted to the immediate neighborhood of the sponges (text-fig. 13). Although sample 164 was taken only

α	β	γ	Malm	
			1	Proteonina compressa
			2	Reophax horridus
			3	Reophax sterkii
			4	Ammobaculites subcretaceus
			5	Ophtalmidium milioliniformis
			6	Trochammina depressa
			7	Dentalina dolioligera
			8	Lagena nodosaroides
			9	Trocholina nodulosa
			10	Brotzenia mosquensis
			11	Brotzenia parastelligera
			12	Lenticulina (Sarac.) gümbeli
			13	Saracenella tricarinata
			14	Dentalina marsupifera
			15	Frondicularia mölleri angusta
			16	Ammobaculites spongiphilus
			17	Bigenerina jurassica
			18	Valvulina lobata
			19	Nodosaria raphanistriformis
			20	Lingulina reticulata
			21	Spirillina polygyrata
			22	Paalzowella feifeli feifeli
			23	Paalzowella feifeli elevata
			24	Paalzowella turbinella
			25	Discobolivina elongata

TEXT-FIGURE 4

Species characteristic of bedded facies, nos. 1–11; non-restricted species, nos. 12–15; species of the sponge marl facies, nos. 16–25. Distribution in the Oxfordian (= Malm *alpha* and *beta*) and in the lower Kimmeridgian (Malm *gamma*).

303
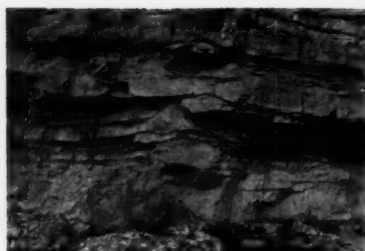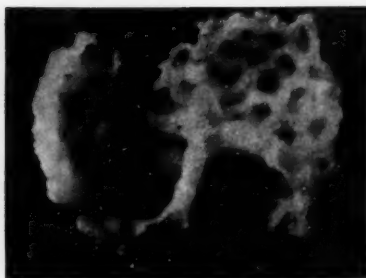
TEXT-FIGURE 5

TEXT-FIGURE 6
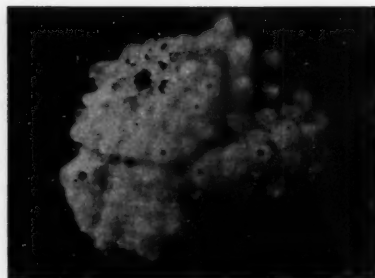
TEXT-FIGURE 7
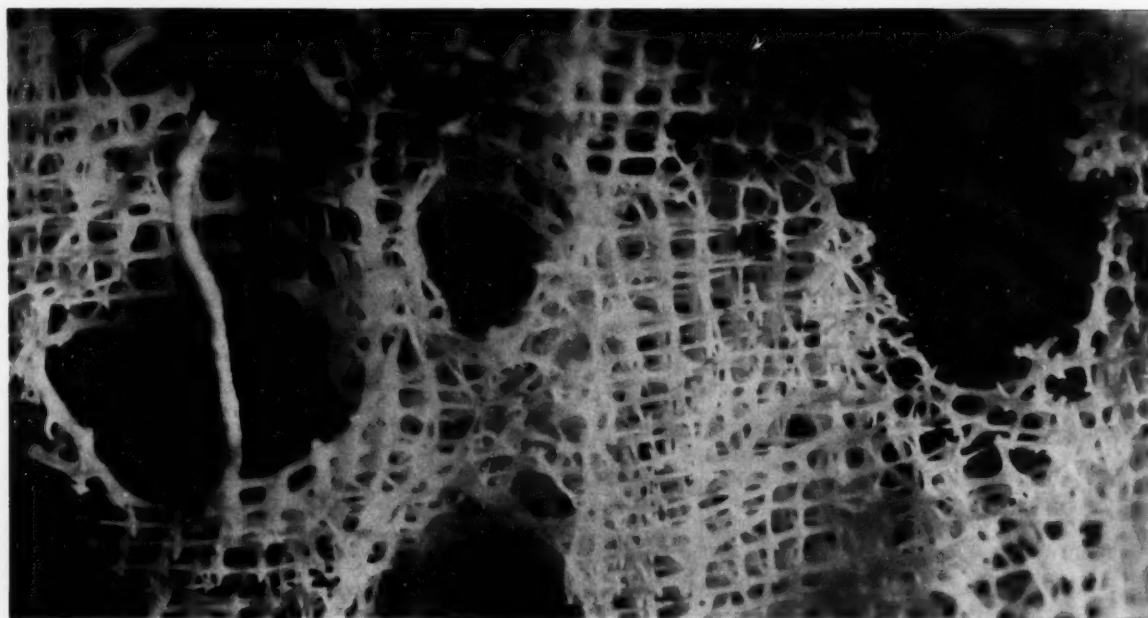
TEXT-FIGURE 8
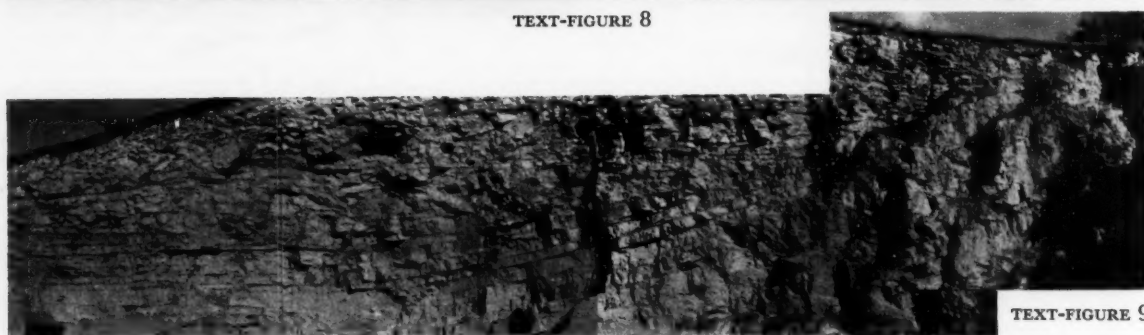
TEXT-FIGURE 9

TEXT-FIGURES 5–9

Foraminifera and sponge bioherms. 5, small sponge bioherm of the eastern Schwaebische Alb (locality Braunenberg), upper Oxfordian; length of the pick, about 0.7 meter. 6 and 7, *Thurammina gracilis* (diameter 1.2 mm.); 6, showing the interior; 7, the exterior; imbedded sponge needles have been etched away. 8, *Tolypammina* sp. *in situ* in the skeleton of a hexactinellid sponge; visible length about 4 mm. 9, sponge bioherm of the western Schwaebische Alb (locality Tieringen), upper Oxfordian; length of the outcrop about 80 meters.
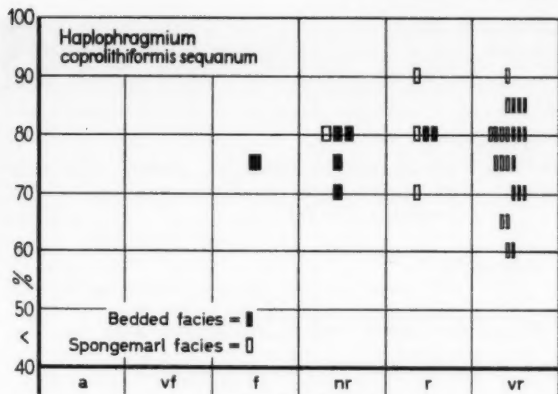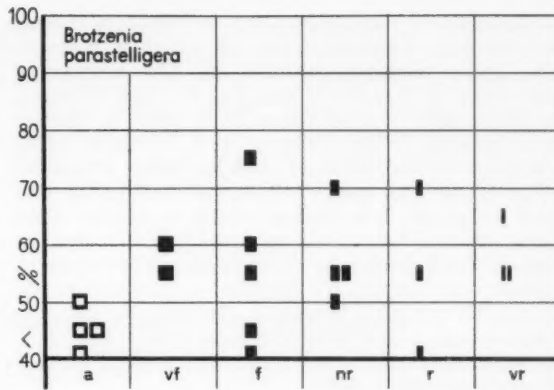
TEXT-FIGURE 10

TEXT-FIGURE 11
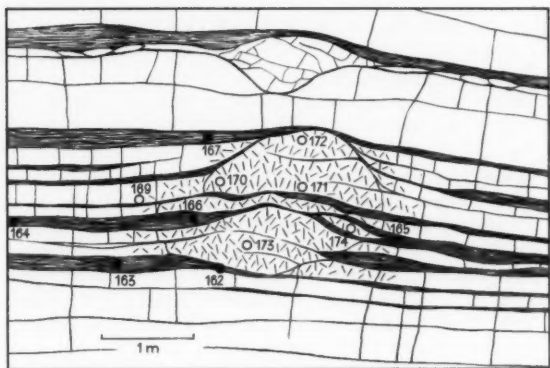
TEXT-FIGURE 12
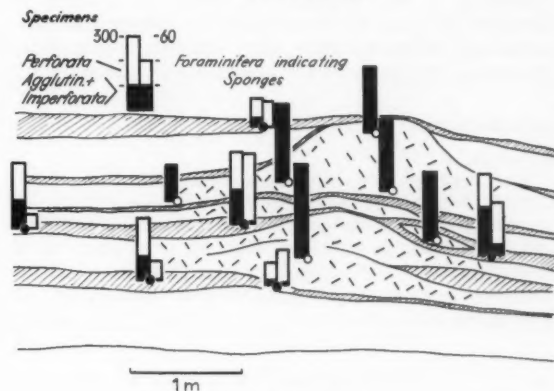
TEXT-FIGURE 13
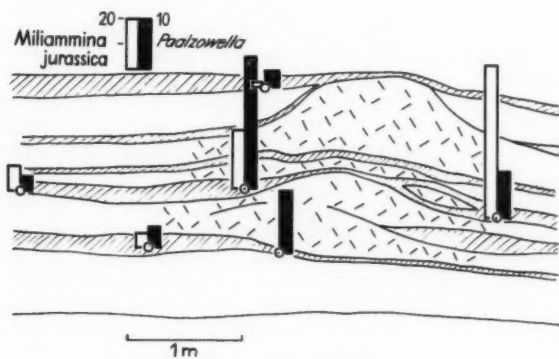
TEXT-FIGURE 14
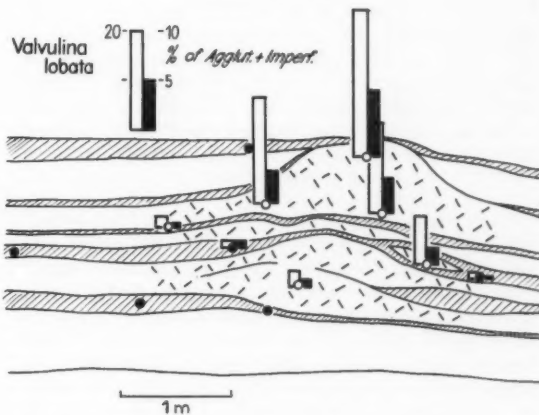
TEXT-FIGURE 15

TEXT-FIGURES 10–15

10 and 11, foraminifera and lime content. Ordinate, percentage of carbonate; abscissa, groups of accumulation as in text-figures 1–3. Each mark represents a sample. 10, *Haplophragmium coprolithiformis sequanum* occurs only in beds rich in lime; 11, *Brotzenia parastelligera* occurs in beds poorer in lime. 12, small sponge bioherm of the eastern Schwaebische Alb (locality Braunenberg), upper Oxfordian. 13, sponge bioherm at Braunenberg; foraminifera indicating sponges (= specimens, right columns of text-fig 13) occur characteristically in the immediate surroundings of the bioherm. This applies to single forms also. 14, *Miliammina jurassica* and *Paalzowella;* 15, *Valvulina lobata.*

305

one meter away from sponges, it contains only 12 of these foraminifera, whereas sample 166, which is closer to the sponge bioherm, contains 58. The number of specimens of *Paalzowella* (text-fig. 14) also decreases rapidly within a few meters from areas of sponge concentration. The siliceous form *Valvulina lobata* (text-fig. 15) was obtained from limestones as well as from marls. This species also occurs abundantly with and in sponges. It is missing entirely in samples taken some distance away from sponges. This fact demonstrates that at least some of the 14 sponge-environment species are extremely sensitive to differences in facies. Of greater importance, however, is the conclusion that, in the vicinity of these sponge bioherms, currents that could have displaced the foraminiferal tests did not exist.

Therefore, it may be said that, in favorable cases, a detailed analysis of foraminifera in relation to the associated sediments may give valuable information concerning the sedimentary conditions in ancient seas.

BIBLIOGRAPHY

FRENTZEN, K.
    1944 – *Die agglutinierenden Foraminiferen der Birmensdorfer Schichten (Transversarius-Zone in Schwammfazies) des Gebietes um Blumberg in Baden.* Palaeont. Zeitschr., vol. 23, pp. 317–342, 2 pls.

GUMBEL, C W.
    1862 – *Die Streitberger Schwammlager und ihre Foraminiferen-Einschlüsse.* Ver. Vaterl. Naturk. Württemberg, Jahresh., vol. 18, pp. 192–238, pls. 3–4.

HOFKER, J.
    1954 – *Über die Familie Epistomariidae (Foram.).* Palaeontographica, vol. 105, pt. A, fasc. 3–6, pp. 166–206, text-figs. 1–7, tables 1–3.

MOHLER, W.
    1938 – *Mikropaläontologische Untersuchungen in der nordschweizerischen Juraformation.* Schweiz. Pal. Ges., Abh. (Soc. Pal. Suisse, Mèm.), vol. 60, pp. 1–53, pls. 1–4, 9 text-figs.

SCHWAGER, C.
    1865 – *Beitrag zur Kenntniss der mikroskopischen Fauna jurassischer Schichten.* Ver. Vaterl. Naturk. Württemberg, Jahresh., vol. 21, pp. 82–151, pls. 2–7.

SEIBOLD, E., AND SEIBOLD, I.
    1959 – *Kalkbankung und Foraminiferen.* Eclogae Geol. Helv. vol. 51, no. 3, pp. 729–737.

    1960 – *Foraminiferen der Bank- und Schwamm-Fazies im unteren Malm Süddeutschlands.* Neues Jahrb. Geol. Pal., Abh., vol. 109, no. 3, pp. 309–438, pls. 7–8, tfs. 1–22.

ABSTRACT: *Employing criteria proposed as an objective basis for the "speciation" of fossil holothurian sclerite morphogroups, the differentiating continuous and discontinuous variates of 1169 topotype specimens of* Rhabdotites, *from the Oxfordian (Upper Jurassic) strata of Redcliff, near Weymouth, Dorset, England, are subjected to univariate statistical analysis. The discontinuous variate of pustule number is shown to be a non-differentiating "specific" character, and the "species" (qua parataxa)* Rhabdotites dorsetensis *Hodson, Harris and Lawson,* R. divergens *Hodson, Harris and Lawson,* R. bifidus *Hodson, Harris and Lawson,* R. tridens *Hodson, Harris and Lawson, and* R. irregularis *Hodson, Harris and Lawson, are placed in the single "species" (qua parataxon)* R. dorsetensis *Hodson, Harris and Lawson, which is revised.*

A statistical analysis of Rhabdotites dorsetensis Hodson, Harris and Lawson, 1956

JOHN S. HAMPTON

Hayes, Bromley
Kent, England

INTRODUCTION

Criteria, based on the results of a statistical analysis of variation patterns in sclerite morphogroups experimentally removed from Recent holothurian biospecies, have recently been proposed as an objective basis, in conjunction with the classification of Frizzell and Exline (1955), for the "species" (*qua* parataxa) concept in fossil holothurian sclerite morphogroups (Hampton, 1959, pp. 347–348). The present study is a demonstration of the applicability of these criteria in a problem of micropaleontology. Apparently undue disregard has been paid to the variation patterns found in fossil holothurian sclerite morphogroups (*op. cit.*, p. 336). Hodson, Harris and Lawson (1956) in a study of such microfossils from the Oxfordian (Upper Jurassic) strata of the Dorset coast, England, erected five new "species" (*qua* parataxa) of the "genus" (*qua* parataxon) *Rhabdotites* Deflandre-Rigaud (1952), and it is proposed to show that those authors' "species" may validly be placed in a single "species" (*qua* parataxon).

HORIZONS, LOCALITY AND MATERIAL

Table 1 shows the relative stratigraphical positions within the Oxfordian (Upper Jurassic) strata at Redcliff, near Weymouth, Dorset, England, from which those samples containing specimens of *Rhabdotites* subjected to statistical analysis were collected. Full details of the zonal stratigraphy and section have been given by Arkell (1947, pp. 33–34 and 51–54), but it should be noted that "hard band 'E'" is an arbitrary level near the top of the Upper Oxford Clay, in the section studied, selected by Hodson *et al.* (1956) purely as a sampling datum bed.

Sample nos. 1 to 6 are the original samples which yielded the sclerites described by Hodson *et al. (op. cit.)*, and although partially picked of the holothurian sclerite

faunas they contained before the present investigation, they still contained such a large number of sclerites as to be considered as random unbiased samples of the original biospecies morphogroups. This was confirmed by comparison with sclerites obtained from another sample (no. 7), which had not previously been examined (see below).

Applying the criteria of Hampton (1959, p. 347) the following procedure was followed:

1) Sample no. 7 was chemically dispersed by a standard technique (Hampton, 1957), as previously had sample nos. 1–6 (Hodson *et al.*, 1956, p. 338). The sample residues were sieved, all fractions not passing through a 200 mesh sieve being retained. These fractions were then completely picked of the holothurian sclerite faunas they contained, except for broken specimens, which were ignored.

2) Those sclerites so obtained and referable to the "genus" (*qua* parataxon) *Rhabdotites* Deflandre-Rigaud (1952), by application of Frizzell and Exline's (1955) classification, were grouped, by application of the criterion of morphological similarity, into a morphogroup for each sample. They were mounted on standard micropaleontological faunal slides. The number of *Rhabdotites* obtained from each sample is shown in Table 2; the total number of specimens obtained for statistical analysis being 1,169.

STATISTICAL ANALYSIS

In the following sections of the text formulae employed in the earlier study of the variation patterns of sclerite morphogroups from Recent holothurian biospecies (Hampton, 1959) are not reiterated, but may be found in the appropriate section of the foregoing work (*op. cit.*,

TABLE 1

Relative stratigraphic positions within the Oxfordian (Upper Jurassic) strata, near Weymouth, Dorset, England, from which those samples containing specimens of *Rhabdotites dorsetensis* Hodson, Harris and Lawson were collected.

SAMPLE NO.	HORIZON
7	Upper Oxfordian, *Cardioceras cordatum* zone *(pars)*, Corallian Beds, Nothe Grits, 6' above the uppermost Oxford Clay (Author's Collection).
6	Lower Oxfordian, *Cardioceras cordatum* zone *(pars)*, Upper Oxford Clay, 11' below "hard band 'E'" (Professor Frank Hodson's Collection).
5	As for sample no. 6, but 12' below "hard band 'E.'"
4	As for sample no. 6, but 13' below "hard band 'E.'"
3	As for sample no. 6, but 14' 6" below "hard band 'E.'"
2	As for sample no. 6, but 15' below "hard band 'E.'"
1	As for sample no. 6, but 38' below "hard band 'E.'"

p. 340). All statistics quoted in the present investigation were computed on an Olivetti "Divisumma 14," electrically operated mechanical calculating machine.

The differentiating continuous variates of the morphogroups of *Rhabdotites* selected for statistical analysis are those of length and breadth, and these were measured on a microscope fitted with an eyepiece graticule on which one division was the equivalent of 0.010526 millimetre. The differentiating discontinuous variate is that of pustule number, which was counted. In no case was a sclerite so examined more than once. The frequencies of values for the variates were plotted for all morphogroups, which in all cases showed unimodal distribution, suggesting unbiased selection of the sclerites and that each morphogroup represented the range of variation of a single sclerite morphogroup (i.e. a "species" (*qua* parataxon)) derived from a single long-ranging biospecies (Hampton, 1959).

Variate 1: Length

To conform with the more general usage of statistical terms (*see* Fisher, 1958, pp. 4, 6), the term *variate* is here used in preference to the term *parameter* previously employed (Hampton, 1959).

Since the seven morphogroups of *Rhabdotites* available for statistical examination were obtained from a series of closely consecutive samples in an approximately continuous stratigraphic sequence within the Oxfordian strata of a single locality (Table 1), it was considered unnecessary to subject the transformed sigmoid curve for the distribution of the continuous variate of length in all morphogroups to probit analysis, but rather only to apply the technique to those morphogroups representing extremes in the sample series. For, as can be seen in Table 2, the values for statistics relating to the variation of the variate are so closely comparable from each morphogroup to the other, that if two morphogroups, obtained from near the base and top of the sample series, are shown to be normally distributed coherent units, then there can be no reasonable doubt that the other morphogroups contained in the series are similarly characterised. A chi-square test was carried out, therefore, following the probit analysis of the transformed sigmoid curve of the distribution of length, on the morphogroups obtained from sample nos. 2 and 7, with the following results:

Sample no. 2: $\chi^2_{[42]} = 1.083$ ($\sqrt{(2\chi^2)} - \sqrt{(2n-1)} = -7.638$ ($P > 0.99$)). Thus there is no suspicion of non-normality or non-linearity of the probit regression line, and it is concluded that the variate of length is unimodally and normally distributed comprising a coherent unit.

Sample no. 7: $\chi^2_{[41]} = 0.262$ ($\sqrt{(2\chi^2)} - \sqrt{(2n-1)} = -8.279$ ($P > 0.99$)). Thus there is no suspicion of non-normality or non-linearity of the probit regression line, and it is concluded that the variate of length is unimodally and normally distributed comprising a coherent unit.

To confirm the above results and the hypothesis that all other morphogroups contained in the sample series are similarly characterised, the Coefficient of Skewness was computed, employing the formula $j \simeq 3 (\bar{x} - m)/\sigma$, where m is the median, $\bar{x}$ the arithmetic mean, and σ the standard deviation (Croxton and Cowden, 1955, p. 227), for all samples, giving the following values:

Sample no.	j
7	0.06
6	0.01
5	0.06
4	0.02
3	0.03
2	0.05
1	0.00

Since the 0.10 moderate skewness value for j is in no case exceeded, it is concluded that the probit analysis results are valid, and that all morphogroups are similarly characterised.

It may safely be assumed, therefore, that in all seven morphogroups the variate of length is unimodally and normally distributed, probably representing an aspect of the natural variation of a single sclerite morphogroup (i.e. a "species" (*qua* parataxon)) of a single long-ranging biospecies.

TABLE 2

Values for statistics characterising the differentiating continuous and discontinuous variates of *Rhabdotites dorsetenssi* Hodson, Harris and Lawson. Unless otherwise indicated all values for the continuous variates are in terms of graticule units, and are corrected to the second decimal place. To convert graticule unit values to millimetres multiply by 0.010526.

SAMPLE NUMBER	NUMBER OF SCLERITES	LENGTH								BREADTH								NUMBER OF PUSTULES	
		O.R.	$\bar{x}$	S.E.	σ	S.E.	4σ	$v(\%)$	S.E. (%)	O.R.	$\bar{x}$	S.E.	σ	S.E.	4σ	$v(\%)$	S.E. (%)	O.R.	%>2
7[1]	110	37–86	63.23[2]	1.01	10.58	0.71	42.32	16.73	1.13	4–11	6.75[3]	0.14	1.45	0.10	5.80	21.54	1.45	2–3	4.55
6	167	40–120	64.04	1.00	12.89	0.71	51.56	20.13	1.10	4–12	6.49	0.13	1.68	0.09	6.72	25.95	1.42	2–3	3.59
5	423	37–110	66.27	0.61	12.52	0.43	50.08	18.89	0.65	4–13	6.84	0.07	1.50	0.05	6.00	21.86	0.75	2–5	4.96
4	210	28–102	64.81	0.87	12.64	0.62	50.56	19.50	0.95	4–13	6.53	0.11	1.57	0.08	6.28	24.03	1.17	2–4	5.71
3	74	39–94	67.09	1.03	8.89	0.73	35.56	13.25	1.10	4–12	5.99	0.17	1.50	0.12	6.00	25.11	2.06	2–3	2.70
2[1]	118	43–97	63.62[4]	1.06	11.47	0.75	45.88	18.03	1.17	3–12	6.62[5]	0.15	1.65	0.11	6.60	24.97	1.63	2–4	6.78
1	67	40–98	65.00	1.55	12.70	1.10	50.80	19.53	1.69	5–10	6.66	0.18	1.50	0.13	6.00	22.52	1.95	2–3	2.99
Pooled	1169	28–120	65.12	0.34	11.70	0.24	46.80	17.97	0.37	3–13	6.64	0.05	1.59	0.03	6.36	23.94	0.50	2–5	4.79

[1] Samples in which the differentiating continuous variates were subjected to probit analysis.

Results for chi-square tests following probit analysis:

[2] $\chi^2_{[41]} = 0.262\ (\sqrt{(2\chi^2)} - \sqrt{(2n-1)} = -8.279\ (P > 0.99))$

[3] $\chi^2_{[6]} = 0.349\ (P > 0.99)\ (P\ 0.05 = 12.59)$

[4] $\chi^2_{[42]} = 1.083\ (\sqrt{(2\chi^2)} - \sqrt{(2n-1)} = -7.638\ (P > 0.99))$

[5] $\chi^2_{[8]} = 1.132\ (P > 0.99)\ (P\ 0.05 = 15.5)$

Since the values of the statistics relating to the variation of length in the seven morphogroups of *Rhabdotites* are closely comparable (see above and Table 2), it is not proposed to treat each individually, but rather as a coherent group of samples within the stratigraphic sequence studied, and in Table 2 it is important to note that the pooled values for all statistics are merely measures of the variational tendency throughout this sequence, rather than measures of the absolute variation characterising the "species" (*qua* parataxon).

The Observed Range *(O.R.)* for the variate of length is 28–120 graticule units (g.u.) (0.295–1.263 mm.); the arithmetic mean ($\bar{x}$) varied between 63.23 and 67.09 g.u. (0.666 and 0.706 mm.), and the Standard Error *(S.E.)* of the mean, from the formula $\sigma/\sqrt{n}$ (Moroney, 1958, p. 137), between ± 0.61 and ± 1.55 g.u. (± 0.006 and ± 0.016 mm.); the standard deviation (σ) ranged between 8.89 and 12.89 g.u. (0.094 and 0.136 mm.), and the *S.E.* of the standard deviation, from the formula $\sigma/\sqrt{2n}$ (*loc. cit.*), between ± 0.43 and ± 1.10 g.u. (± 0.005 and ± 0.012 mm.), the values for 4σ lie between 35.56 and 51.56 g.u. (0.374 and 0.543 mm.). Thus the range in which 99.994% of the total population (of length) in *Rhabdotites* will lie is $\bar{x} \pm 4\sigma$ (Hampton, 1959, p. 340), and is approximately 65.12 $\pm$ 46.80 g.u. (0.685 $\pm$ 0.493 mm.) (Table 2).

An indication of the relative variability of the variate was obtained from the formula for the Coefficient of Variation, $v = 100\sigma/\bar{x}$ (Moroney, 1958, p. 64), and ranged between 13.25 and 20.13% with a *S.E.*, from the formula $v/\sqrt{2n}$ (*op. cit.*, p. 137), of between ± 0.65 and $\pm 1.69\%$.

From the results of the univariate statistical analyses of the differentiating continuous variate of length in the morphogroups of *Rhabdotites* obtained from the sample series, it may be assumed with confidence that the various sclerites they contain, previously placed in five "species" (*qua* parataxa) (Hodson *et al.*, 1956), belong to a single sclerite morphogroup (i.e. a "species" (*qua* parataxon)) of a single long-ranging biospecies.

Variate 2: Breadth

For the same reasons as given when considering the differentiating continuous variate of length (see above), a chi-square test was carried out, following the probit analysis of the transformed sigmoid curve of the distribution of breadth, on the morphogroups obtained from samples nos. 2 and 7, with the following results:

Sample no. 2: $\chi^2_{[8]} = 1.132\ (P > 0.99)$.

Thus, there is no suspicion of non-normality or non-linearity of the probit regression line, and it is concluded

that the variate of breadth is unimodally and normally distributed, comprising a coherent unit.

Sample no. 7: $\chi^2_{[6]} = 0.349 \ (P > 0.99)$

Thus there is no suspicion of non-normality or non-linearity of the probit regression line, and it is concluded, that the variate of breadth is unimodally and normally distributed, comprising a coherent unit.

To confirm the above results and the hypothesis that all other morphogroups contained in the sample series are similarly characterised, the Coefficient of Skewness was computed for all samples, giving the following values:

Sample no.	j
7	0.05
6	0.03
5	0.02
4	0.03
3	0.07
2	0.02
1	0.04

Since the 0.10 moderate skewness value for j is in no case exceeded, it is concluded that the probit analysis results are valid, and that all morphogroups are similarly characterised.

It may safely be assumed, therefore, that in all seven morphogroups the variate of breadth is unimodally and normally distributed, probably representing an aspect of the natural variation of a single sclerite morphogroup (i.e. a "species" (*qua* parataxon)) of a single long-ranging biospecies.

Since, as in the case of the variation of length (see above), the values for the statistics relating to the variation of breadth in the seven morphogroups of *Rhabdotites* are closely comparable (see above and Table 2), it is not proposed to treat each individually, but rather as a coherent group of samples within the stratigraphic sequence studied.

O.R. 3 to 13 g.u. (0.032 to 0.137 mm.); $\bar{x}$ 5.99 to 6.84 g.u. (0.063 to 0.072 mm.), and *S.E.* ± 0.07 to ± 0.18 g.u. (± 0.001 to ± 0.002 mm.); σ 1.45 to 1.68 g.u. (0.015 to 0.018 mm.), *S.E.* ± 0.05 to ± 0.13 g.u. (± 0.0005 to ± 0.0014 mm.), and 4σ 5.80 to 6.72 g.u. (0.061 to 0.081 mm.); $\bar{x} \pm 4\sigma$ approximately 6.64 ± 6.36 g.u. (0.070 ± 0.067 mm.); v 21.54 to 25.95%, and *S.E.* ± 0.75 to $\pm 2.06\%$.

From the results of the univariate statistical analyses of the differentiating continuous variate of breadth in the morphogroups of *Rhabdotites* obtained from the sample series, it may be assumed with confidence that the various sclerites they contain, previously placed in five "species" (*qua* parataxa) (Hodson *et al.*, 1956), belong to a single sclerite morphogroup (i.e. a "species" (*qua* parataxon)) of a single long-ranging biospecies.

Coefficient of Correlation

Although r is here obtained by using the formula $S(x-\bar{x})(y-\bar{y}) \ / \ n\sigma_x\sigma_y$ (*see* Hampton, 1959, p. 340), which is generally employed in statistical work, a more readily computable expression for the statistic is $1-6Sd^2/n(n^2-1)$, where S denotes summation, d the difference between the pairs of variates, and n the number of pairs, which gives results differing slightly from those given by the former expression (*see* Page, 1958, p. 126).

TABLE 3

Values for the Coefficient of Correlation between the differentiating continuous variates of length and breadth in *Rhabdotites dorsetensis* Hodson, Harris and Lawson.

Sample no.	r	t	P
7	+ 0.094	0.981	$< 0.4 > 0.3$
6	+ 0.251	3.350	< 0.001
5	+ 0.876	37.270	< 0.001
4	+ 0.520	8.779	< 0.001
3	+ 0.028	0.024	> 0.9
2	+ 0.232	2.644	$< 0.02 > 0.01$
1	+ 0.118	0.958	$< 0.4 > 0.3$
Pooled	+ 0.591	24.818	< 0.001

Table 3 shows the values for r between the differentiating continuous variates of length and breadth in the seven morphogroups of *Rhabdotites* studied. The considerable variation of the values results largely from the small number of sclerites contained in some morphogroups (see Table 1), and little significance may be attached to those estimations based on less than 100 sclerites. However, values for t, from the formula $t = r\sqrt{(n-2)} / \sqrt{(1-r^2)}$ (Moroney, 1958, p. 311), show that only three of the r values are insignificant at 0.05 probability level. The r values were, therefore, pooled by applying Fisher's z transformation (*op. cit.*, p. 312), and gave a pooled estimate for r of $+0.591$, the value of 24.818 for t shows this correlation to be highly significant ($P < 0.001$), and it is concluded, therefore, that in any sufficiently large sample of *Rhabdotites*, from the *Cardioceras cordatum* zone of the Oxfordian at Redcliff, near Weymouth, Dorset, England, a fairly positive correlation between the differentiating continuous variates of length and breadth will be detectable.

Statistical discrimination of the morphogroups

Since it has been shown that all seven morphogroups of *Rhabdotites* in the sample series investigated, were probably derived from a single sclerite morphogroup (i.e. a "species" (*qua* parataxon)) of a single long-ranging biospecies, it is essential to demonstrate that the arithmetic mean values for the respective differentiating continuous variates do not differ significantly at the 0.05 probability level from morphogroup to morphogroup. To compare the arithmetic mean values of two

samples, however, it is necessary to assume that $\sigma_1 = \sigma_2$ (Hoel, 1956, p. 233), and in order to confirm this assumption the equality of the two sample variances must be demonstrated by application of Snedecor's F (variance ratio) test. Now F = Greater variance estimate/Lesser variance estimate (i.e. $F = \sigma_1^2/\sigma_2^2$ or σ_2^2/σ_1^2, whichever is the larger). When computed for *Rhabdotites* the following results were obtained:

Sample variances compared	Length		Breadth	
	F	P	F	P
7 to 1	1.44	> 0.05 < 0.10	1.07	> 0.20
6 to 1	1.03	> 0.20	1.25	> 0.20
5 to 1	1.03	> 0.20	1.00	> 0.20
4 to 1	1.01	> 0.20	1.10	> 0.20
3 to 1	2.04	> 0.01 < 0.05	1.00	> 0.20
2 to 1	1.23	> 0.20	1.21	> 0.20

Since the value for F exceeds the 5% probability level in only one case (that of length in the morphogroup obtained from sample no. 3), and in that case only barely so, it is concluded that the sample variances sufficiently approach equality to allow comparison between their respective arithmetic mean values. Table 4 shows results obtained for "Student's" t-test (Hampton, 1959, p. 344) in which sample nos. 2 to 7 were compared with sample no. 1. In one case only (that of breadth in the morphogroup obtained from sample no. 3) the value for t indicates a significant difference, and this probably resulted from either the small number of sclerites in the morphogroup, or from biasing by picking prior to the present investigation. However, since all other values for t indicate insignificant differences, it may be assumed with confidence that all data may validly be pooled for both length and breadth, the anomalous value being so small as to be masked in the pooled morphogroup. Since all morphogroups, obtained from the sample series, are, therefore, directly comparable it is concluded that they were derived from a single sclerite morphogroup (i.e. a "species" (*qua* parataxon)) of a single long-ranging biospecies.

TABLE 4

Comparisons of arithmetic mean values for the differentiating continuous variates of length and breadth in *Rhabdotites dorsetensis* Hodson, Harris and Lawson, by "Student's" t-test.

Samples Compared	Length		Breadth	
	t	P	t	P
7 to 1	1.618	> 0.1 < 0.2	0.604	> 0.5 < 0.6
6 to 1	0.547	> 0.5 < 0.6	0.744	> 0.4 < 0.5
5 to 1	0.793	> 0.4 < 0.5	0.924	> 0.3 < 0.4
4 to 1	0.112	> 0.9	0.619	> 0.5 < 0.6
3 to 1	1.322	> 0.1 < 0.2	2.840	> 0.001 < 0.01
2 to 1	0.827	> 0.4 < 0.5	0.162	> 0.8 < 0.9

Variate 3: Pustule number

Since pustule number is directly related to sclerite branching, the fundamental question in any consideration of "speciation" in *Rhabdotites* is whether, or not, the discontinuous variate represents a differentiating "specific" character.

Hodson *et al.* (1956) employed the characters of branching and pustule number as criteria for the "speciation" of *Rhabdotites*, erecting five new "species" (*qua* parataxa), the present author considers, however, that these "species" may validly be placed in but one "species" (*qua* parataxon), and that insufficient regard has been paid to the variation patterns found within sclerite morphogroups (Hampton, 1959, p. 336).

Woodland (1906) has demonstrated that the morphology of holothurian sclerites is absolutely controlled by the cellular behaviour of the scleroblastic syncytia producing them, and it is apparent, therefore, that the manner in which such scleroblastic syncytia function is a feature of the genetic autonomy of the biospecies containing them. Thus each biospecies will probably be characterised by distinctive sclerite morphogroups showing considerable variation (Hampton, 1959), *each sclerite reflecting the nature of the scleroblastic syncytium in which it was produced*. The cells of the scleroblastic syncytium produce "calcite" granules which are formed into a primary structure (e.g. a rod, or a cross (Frizzell and Exline, 1955, p. 9)), the cells may then re-arrange within the syncytium and produce secondary structures to the primary structure. This process may be repeated until highly complex sclerites are formed, or may merely cease on the completion of the primary structure, depending upon the biospecies involved. Thus in any holothurian biospecies the scleroblastic syncytia would be expected to produce sclerite morphogroups in which the distribution of the differentiating discontinuous variates is non-random, with very marked distributional peaks for the "characteristic form" of the variates. In the Recent aspidochirotid holothuroid *Holothuria impatiens* (Forskäl) the characteristic perforated plate has typically 6 holes (Hampton, 1959, p. 342, plate 1, figs. 1c, 2c), and the sclerites with that number of holes form a very apparent peak in the distribution of the variate, comprising between 83 and 97 per cent of the total number of perforated plates examined, whereas those sclerites having more than 6 holes comprise but between 3 and 7 per cent of the total number. In the Recent denrochirotid holothuroid *Cucumaria saxicola* Brady and Robertson the characteristic perforated plate has typically 4 holes (*op. cit.*, p. 346, plate 1, fig. 3c), and the sclerites with that number of holes form a very apparent peak in the distribution of the variate, comprising 54 per cent of the total number of perforated plates examined, whereas those sclerites having more than 4 holes comprise but 13 per cent of the total number. It seems probable, therefore, that the differentiating discontinuous variate of the perforated plates in the two biospecies discussed is non-randomly distributed.

Now in *Rhabdotites* the syncytia characteristically produced rods having 2 pustules, and occasionally rods having 3, 4, and 5 pustules. Thus if such sclerites were produced by a single biospecies it could be expected, by analogy to the distribution of the discontinuous variates in sclerite morphogroups from Recent holothurians, that pustulation would probably be non-randomly distributed, with those sclerites having 2 pustules forming a very apparent peak in the distribution, and those sclerites having more than that number of pustules comprising a very small but reasonably constant percentage of the total number of sclerites. Those sclerites having 2 pustules form a very marked peak in the distribution of the variate, comprising between 93 and 97 per cent of the total number of rods examined, whereas those sclerites having more than two pustules comprise but between 3 and 7 per cent of the total number (Table 2). It appears highly probable, therefore, that pustulation, along with branching, in *Rhabdotites* is non-randomly distributed and cannot be considered as a differentiating "specific" character.

The hypothesis may be further tested as follows: since the variate forms a truncated discontinuous distribution in which the values for the variable are confined to a series of whole numbers 2, 3, 4, and 5 (0 and 1 not being recognised since they represent initial stages in sclerite formation), if the relative frequencies with which the values occur are given by the terms of an appropriately truncated Poisson series, then the variate is randomly distributed in the Poisson distribution. Since the single samples contained insufficient sclerites to validly test the goodness of fit, only the pooled sample was considered, and this had an apparent mean number of pustules of 2.06. Now a truncated Poisson series with an apparent mean of 2.06 has a true mean for the Poisson distribution of 0.20. However, the observed number of sclerites in the pooled sample differs so greatly from the number of sclerites expected in the truncated Poisson series, that it is highly probable that the variate is non-randomly distributed. To confirm this view a chi-square test (Moroney, 1958, pp. 250 and 96–104) was carried out, giving a value for $\chi^2_{(1)}$ of 10.817 ($P < 0.01$), which is so great as to refute the Null Hypothesis that the discrepancy between the observed and expected number of sclerites could have arisen by chance. Similar experiments on the differentiating discontinuous variates of the perforated plates from *Holothuria impatiens* (Forskäl) and *Cucumaria saxicola* Brady and Robertson, also gave results indicating highly significant departure from expectation.

It is concluded, therefore, that pustulation in *Rhabdotites* is non-randomly distributed reflecting an aspect of the natural variation of a single sclerite morphogroup (i.e. a "species" (*qua* parataxon)) of a single long-ranging biospecies, and that the variate is not randomly distributed in the Poisson distribution. The variate cannot, therefore, be considered as a differentiating "specific" character and the "species" (*qua* parataxa) *Rhabdotites dorsetensis* Hodson, Harris and Lawson, *R. divergens* Hodson, Harris and Lawson, *R. bifidus* Hodson, Harris and Lawson, *R. tridens* Hodson, Harris and Lawson, *R. irregularis* Hodson, Harris and Lawson, may validly be best placed in the single "species" (*qua* parataxon) *Rhabdotites dorsetensis* Hodson, Harris and Lawson.

Pustulation in *Rhabdotites* appears to have occurred as a secondary event after the completion of the primary body of the rod, the function of the pustules seems, most probably, to have been to anchor the sclerite into the syncytium.

Assuming that the percentages of sclerites having 2, 3, 4, and 5 pustules in the pooled sample are related to the probability of the occurrence of 2, 3, 4, and 5 pustules occurring within the population studied, it may be expected that in any sufficiently large sample of *Rhabdotites*, from the *Cardioceras cordatum* zone of the Oxfordian at Redcliff, near Weymouth, Dorset, England, the probability of 2 pustules occurring is approximately 0.9521, of 3 approximately 0.0368, of 4 approximately 0.0086, and of 5 approximately 0.0026.

SYSTEMATIC PALEONTOLOGY

<div align="center">

Phylum ECHINODERMATA
Class HOLOTHUROIDEA
Family STICHOPITIDAE Frizzell and Exline
Genus RHABDOTITES Deflandre-Rigaud, 1952

</div>

<div align="center">

Rhabdotites dorsetensis Hodson, Harris and Lawson,
revised Hampton
Plate 1

</div>

Rhabdotites dorsetensis Hodson, Harris and Lawson, 1956, Geol. Mag., vol. 93, no. 4, p. 341, text-figs. 5, 6, 7 (in part), 15, 20, 21.
Rhabdotites divergens Hodson, Harris and Lawson, 1956, Geol. Mag., vol. 93, no. 4, p. 342, text-figs. 14, 17, 18.
Rhabdotites bifidus Hodson, Harris and Lawson, 1956, Geol. Mag., vol. 93, no. 4, p. 342, text-figs. 16, 22.
Rhabdotites tridens Hodson, Harris and Lawson, 1956, Geol. Mag., vol. 93, no. 4, p. 343, text-fig. 19.
Rhabdotites irregularis Hodson, Harris and Lawson, 1956, Geol. Mag., vol. 93, no. 4, p. 343, text-fig. 25.

<div align="center">

PLATE 1

</div>

Camera-lucida drawings of topotype specimens of *Rhabdotites dorsetensis* Hodson, Harris and Lawson, selected from sample no. 4 (Table 1), ca. × 40. When first described the variants of this "species" (*qua* parataxon) where placed in five separate "species" (*qua* parataxa) (Hodson *et al.*, 1956), statistical analysis shows, however, that these forms belong to a single sclerite morphogroup (i.e. a "species" (*qua* parataxon)) of a long-ranging biospecies.
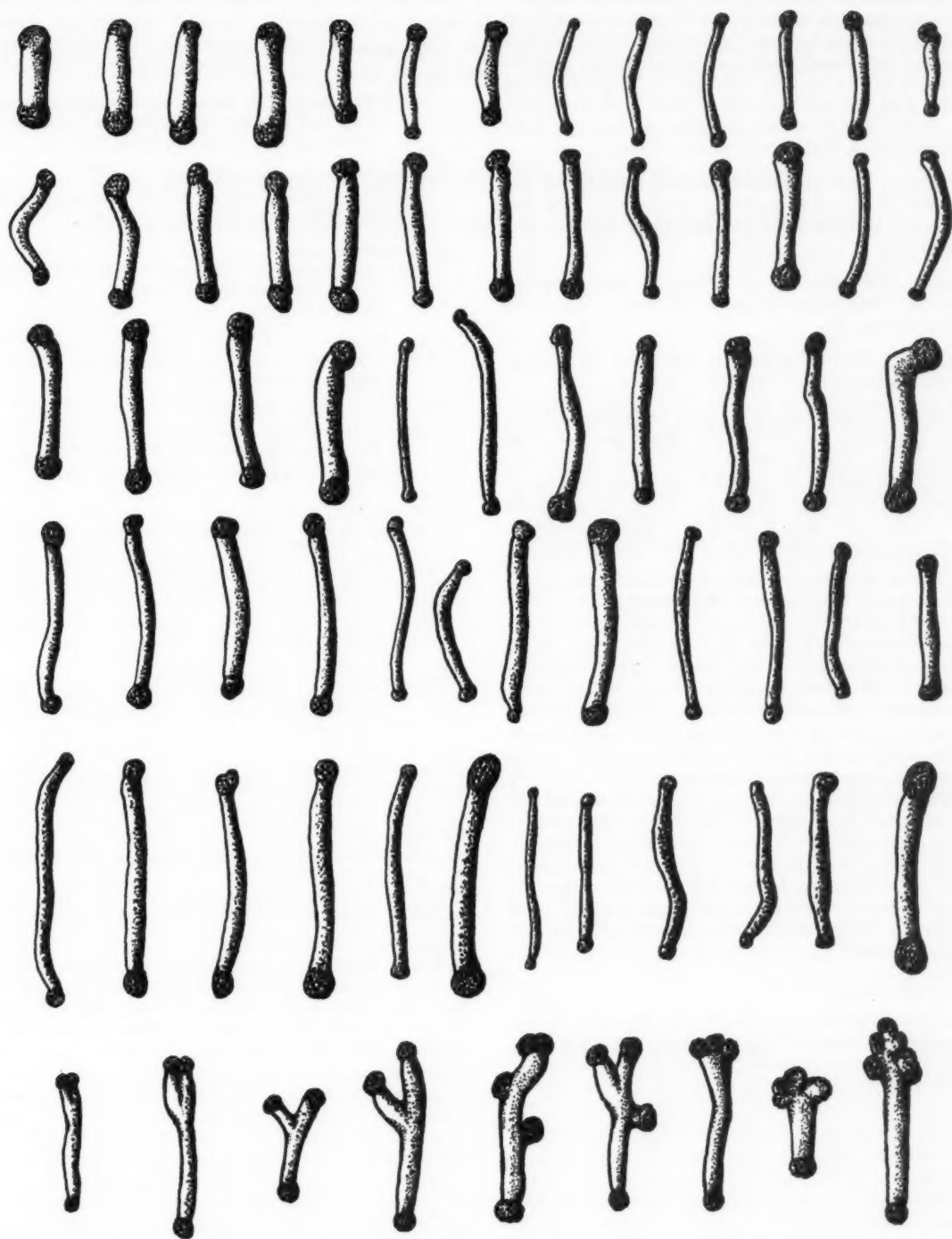
Revised description: Holothurian endoskeletal sclerites, comprising a single sclerite morphogroup (i.e. a "species" (*qua* parataxon)) of a single long-ranging biospecies, in the form of straight or gently arcuate, unbranched or branched rods, usually with regular or irregular pustules developed at the terminal extremities. Typically being slender and unbranched with a pustule at each end, rods more rarely occurring with distinct or fused branches and 3, 4, or 5 (or more) pustules.

Dimensions: Table 2 shows statistics relating to the variation of the differentiating continuous and discontinuous variates characterising the "species" (*qua* parataxon).

Holotype: Specimen No. J 35794 in the Sedgwick Museum, Cambridge, England (Hodson *et al.*, 1956, p. 341, text-fig. 20).

Type locality: Redcliff, 3 miles northwest of Weymouth, Dorset, England (*op. cit.*, p. 337).

Distribution: Upper Jurassic; Lower Oxfordian, uppermost 50 feet (or so) in the *Cardioceras cordatum* zone (*pars*) of the Upper Oxford Clay (Type Level (*loc. cit.*)); Upper Oxfordian, *Cardioceras cordatum* zone (*pars*) Nothe Grits (Corallian Beds), and *Perisphinctes plicatilis* zone Nothe Clay and Bencliff Grit (Corallian Beds) (Hampton, *unpublished research*), of the type locality.

Remarks: All morphologic forms of *Rhabdotites* placed by Hodson *et al.*, (1956, pp. 341–343, text-figs. 14–22, 25) into five separate "species" (*qua* parataxa), have been observed along with other variants (Plate 1) during the present investigation, and the univariate statistical analyses of the differentiating variates have shown that beyond any reasonable doubt the various types encountered are in fact variational aspects of a single sclerite morphogroup (i.e. a "species" (*qua* parataxon)) of a single long-ranging biospecies. Furthermore, the variation observed in this fossil sclerite morphogroup is so consistent, by analogy, with that of sclerite morphogroups derived from Recent holothurian biospecies, that the hypothesis may be considered proven with confidence. Therefore, Hodson's *et al.* (1956) "species" (*qua* parataxa) are placed in the single "species" (*qua* parataxon) *Rhabdotites dorsetensis* Hodson, Harris and Lawson, as redefined above.

ACKNOWLEDGMENT

BIBLIOGRAPHY

ARKELL, W. J.
1947 – *The geology of the Country around Weymouth, Swanage, Corfe and Lulworth.* Great Britain, Geol. Survey, Mem., pp. 386, 19 pls., 84 text-figs., map.

CROXTON, F. E., AND COWDEN, D. J.
1955 – *Applied general statistics.* London: Pitman and Sons, 2nd. ed.

DEFLANDRE-RIGAUD, M.
1952 – *Contribution à la systematique des sclerites d'holothurides fossiles.* Monaco, Inst. Océanogr., Bull., no. 1012, pp. 1–15.

FISHER, R. A.
1958 – *Statistical methods for research workers.* Edinburgh: Oliver and Boyd, 13th. ed.

FRIZZELL, D. L., AND EXLINE, H.
1955 – *Monograph of fossil Holothurian sclerites.* Missouri Univ., School Mines Metall., Bull., Tech. Ser., no. 89, pp. 1–204, pls. 1–11, text-figs. 1–21, table 1.

HAMPTON, J. S.
1957 – *A dispersion technique.* Museums Jour., vol. 56, no. 12, pp. 284–285.
1959 – *Statistical analysis of holothurian sclerites.* Micropaleontology, vol. 5, no. 3, pp. 335–349, pls. 1–4, text-figs. 1–3.

(Ms) – *Statistical analysis of fossil holothurian sclerites.*

HODSON, F., HARRIS, B., AND LAWSON, L.
1956 – *Holothurian spicules from the Oxford clay of Redcliff, near Weymouth (Dorset).* Geol. Mag., vol. 93, no. 4, pp. 336–344, text-figs. 1–25.

HOEL, P. G.
1956 – *Introduction to mathematical statistics.* New York: John Wiley and Sons, 2nd. ed.

MORONEY, M. J.
1958 – *Facts from figures.* Middlesex. Penguin Books: 3rd. ed.

PAGE, A.
1958 – *Algebra.* Univ. London Press: London. 5th. Imp.,

WOODLAND, W.
1906 – *Studies in spicule formation. IV – The scleroblastic development of the spicules in Cucumariidae; with a note relating to the plate–and–anchor spicules of Synapta inhaerens.* Quart. Jour. Micr. Sci., vol. 49, pt. 4, pp. 533–559, pls. 32–34.

ABSTRACT: *Four genera*, Praeglobotruncana, Planomalina, Globigerinella, *and* Biglobigerinella, *are shown to be different developmental stages of single biological units. Three of these units can be followed in their development passing through these artificial "genera," the stages having been named as different artificial "species." One unit began and ended in the Albian; a second one began in the Albian and ended in the upper Maestrichtian; and a third one began in the Danian and has not yet fully ended in the Recent. Such artificial genera have no taxonomic value, and appear to be totally invalid.*

The taxonomic status of Praeglobotruncana, Planomalina, Globigerinella, and Biglobigerinella

JAN HOFKER
The Hague

In a paper on planktonic foraminifera, Bolli, Loeblich, and Tappan (1957) gave their views on the following four genera: *Praeglobotruncana* Bermudez, 1952 (pp. 39–40); *Planomalina* Loeblich and Tappan, 1946 (pp. 23–24); *Globigerinella* Cushman (see *Hastigerina* Thomson, 1876; pp. 29–30); and *Biglobigerinella* Lalicker, 1948 (p. 25). According to these authors, species of so-called *Globigerinella* from the Mesozoic belong to other genera, viz., *Planomalina*, *Biglobigerinella*, and *Globigerinelloides* Cushman and ten Dam (p. 29); the Recent form *Globigerinella aequilateralis* (Brady) is thought to belong to *Hastigerina*.

According to Bolli, Loeblich, and Tappan, *Praeglobotruncana* Bermudez is a trochoid form, with an interiomarginal aperture forming a relatively high and open extraumbilical-umbilical arch bordered by a narrow lip or spatulate flap, which is commonly directed toward the umbilicus and often forms a serrate or scalloped border around the umbilicus. *Planomalina* Loeblich and Tappan is planispiral and biumbilicate; some species are known with a slight keel, but most forms are smooth at the margin; the aperture is interiomarginal, an equatorial arch with lateral extensions reaching back on either side to the septum at the base of the chamber, the lateral umbilical portions of successive apertures remaining open as supplementary relict apertures after the equatorial portion is covered by the succeeding chambers. *Globigerinella* Cushman, incorporated by these authors into *Hastigerina* Thomson, may be slightly trochospiral in the early stages, but the adult is planispiral, with an interiomarginal aperture, a broad equatorial arch. *Biglobigerinella* Lalicker, according to these authors, is planispiral, nearly or completely involute, with a broadly ovate end chamber which may finally be replaced by two paired chambers; the aperture is interiomarginal, equatorial, a simple low arch in the early stages; in the later paired chambers there is one extraumbilical aperture in each chamber of the final pair. All four genera show fine pores except for some Recent and Tertiary species of *Globigerinella*.

Hofker (1957) showed that in the *Globigerina aspera* group the first stage of development of the whole series is a flat trochoidal form (*Globigerina aspera* forma *trochoidea* Hofker, from the Cenomanian), which by gradual development becomes more and more planispiral (*Globigerina aspera* forma *subplana* Hofker in the upper Santonian, and *Globigerina aspera* forma *plana* Hofker in the Campanian and Maestrichtian). In the Maestrichtian, a form develops with the arched equatorial aperture split into two more laterally placed apertures, giving rise at the end of the development to forms not distinguishable from *Biglobigerinella* Lalicker (*Globigerina biforaminata* Hofker, 1956). Such a gradual development through different genera should make us suspicious of the taxonomic value of such genera.

Sigal (1956a) described as *Biticinella breggiensis* (Gandolfi) a form from the Vraconian of Tunisia that must in reality be a *Planomalina*, according to the description of that genus given by Loeblich et al. Sigal's description (1956b) of *Planomalina buxtorfi*, however, distinctly shows (see his text-figure on p. 212) that the apertural conditions of that species (which has a marginal keel) are quite different from those described by Loeblich et al. for *Planomalina*. Moreover, Sigal (1958) noted that, "dans certaines faunes nord-africaines," several forms are found together which obviously belong to a single species but show the characters of *Globigerinelloides*, *Globigerinella*, and *Biglobigerinella*. (We must bear in mind that Sigal's concept of *Globigerinelloides* is the same as Loeblich's concept of *Planomalina*.) Sigal notes "comme une réelle entité biologique démontrerait une fois de plus, si elle est exacte, combien nos genres sont artificiels."

The present author has obtained excellently preserved material from a well penetrating more than 100 meters of Albian clays in the Netherlands. Many of the foraminiferal specimens are filled with air. Cores were taken every 5 meters, so that a fairly continuous series of samples could be studied. Planktonic species were often abundant.

In the lowermost 20 meters of the section, among many other species, a small form was found which must be referred to *Praeglobotruncana* Bermudez. This species shows a flat trochoidal spire, totally visible on the dorsal side, while on the ventral side the chambers are more elongate, leaving a small umbilicus free. The margin is rounded, with no trace of a poreless keel; there are usually seven chambers in the last-formed whorl, and the aperture is interiomarginal, ventral, directed toward the umbilicus, more or less arched and with a distinct lip above it.

From bottom to top of the lowermost 20 meters, more and more specimens are found in which the umbilicus is more conspicuous, the spire is nearly flat, and the arched aperture migrates more and more toward the margin, never, however, becoming fully equatorial. In the next higher 10 meters, more and more specimens appear in which the dorsal spire becomes indistinct and depressed at the center, forming a shallow umbilical hollow, while the arched aperture becomes more and more equatorial, and, on the ventral side, the flap over the aperture points more and more toward the base of the previous chamber, thus acquiring the character of the flaps in *Planomalina*. In most of the specimens, however, the dorsal side differs from the ventral in not showing distinct apertures.

Beginning 30 meters above the base of the section studied, most of the specimens show a planispiral test with distinct lateral parts of the aperture on one side and with indistinct lateral apertures on the other side. At 40 meters above the base, all specimens observed show the lateral portions of the apertures on both sides of the test, most of them having a large arched equatorial aperture curving toward both sides of the test and there forming the backwardly directed rimmed lateral portions. Some specimens, however, show a distinct projection of the lip over the aperture at the middle of the marginal part of the aperture; the projection curves toward the margin and often reaches the outer wall of a chamber at the beginning of the last-formed whorl, thus dividing the aperture into two portions, both laterally placed. This phenomenon continues throughout the upper 20 meters of the section, and at the top many specimens not only show the two apertures, but also have formed two chambers over these apertures, giving rise to the *Biglobigerinella* type.

Just as in the *Globigerina aspera* group during the Cenomanian to upper Maestrichtian, we have here a quite similar orthogenetic developmental series and an affirmation of the observation made by Sigal. Since the form that occurs at about 40 meters above the base of the section is identical with what was described by Loeblich *et al.* as *Planomalina caseyi* Bolli, Loeblich and Tappan (1957, p. 24, pl. 1, figs. 4–5), the group may be referred to as the *Globigerina caseyi* group.

In the *Globigerina aspera* group, the development shows stages from *Globigerina* through *Globigerinella* to *Biglobigerinella*, where the group ends. In the *Globigerina caseyi* group, it begins with typical *Praeglobotruncana*, runs through *Planomalina*, and again ends with *Biglobigerinella*, since the group is no longer found in samples from above the 60-meter level mentioned, although the facies remains the same and other planktonic species are still abundant.

It appears that among the globigerines, in all cases in which a trochoidal form evolves into a planispiral one, the latter ends with the formation of two lateral apertures and, in its most highly developed stage, forms two chambers arranged perpendicularly to the plane of coiling. It is obvious that such developmental series cannot give rise to new groups; they always seem to form the end of a phyletic line in *Globigerina*. It is thus obvious that the hypothesis of Bolli, Loeblich and Tappan that *Praeglobotruncana* was ancestral to *Globorotalia* and other groups lacks support. *Praeglobotruncana* comprises a group of globigerines which tended to become planispiral and appear to have invariably ended in the blind alley of *Biglobigerinella*, with two last-formed chambers.

All globigerines found in the Albian show a laterally placed interiomarginal aperture provided with a covering flap, which is always poreless (probably a toothplate); moreover, several of them show behind that flap a small indentation at the suture with the previous chamber, very probably a protoforamen. Thus, all globigerines of the Albian show more or less the characters of *Praeglobotruncana*. In the Cenomanian, some of them have the apertures displaced more and more toward the ventral umbilical hollow, so that the aperture becomes umbilical, and the poreless flaps then cover part of the umbilical hollow. In this way the *Globigerina cretacea* type is reached, which at the end of its developmental sequence shows the characters of the form called *Rugoglobigerina* (type *Globigerina rugosa* Plummer). However, since many groups of foraminifera, at the end of their developmental history, tend to show characters that occurred at the beginning of the development of the group, the *Globigerina cretacea* group in its final stage may also have redeveloped interiomarginal apertures, as in *Globigerina compressa* Plummer (that species is not, as has been suggested, a *Globorotalia*, because the poreless keel is entirely absent).

Thus we find that the taxonomy of planktonic foraminifera of the group of *Globigerina* is not as simple as Bolli, Loeblich, and Tappan believe. We find several developmental series with a gradual orthogenetic change of characters, which shows that these genera, as established by their authors, cannot be true natural genera. They are artificial; a single biological entity, during its development in time, passes through several of these artificial genera. Within these "genera," distinct "species" have been established, thoroughly valid according to the Rules of Nomenclature but having no real biological significance, as their boundaries are indistinct. We must therefore return to what was called by Vaughan (1905) the "gens." We have here described the beginning and the end of two different "gentes,"
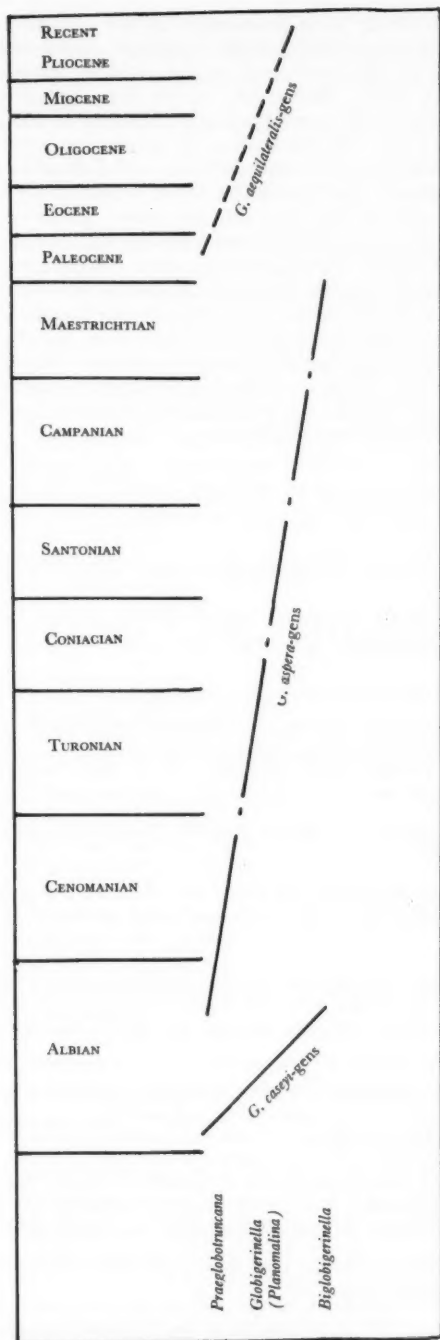
TEXT-FIGURE 1

Orthogenesis of the three gentes *Globigerina caseyi*, *Globigerina aspera*, and *Globigerina aequilateralis* during time, passing through the "*Praeglobotruncana*," "*Globigerinella*," and "*Biglobigerinella*" stages.

one of which may be called the *Globigerina aspera* (Ehrenberg) gens and the other the *Globigerina caseyi* (Bolli, Loeblich, and Tappan) gens. Both pass through several artificial genera and, obviously, through several of the artificial species assigned to those genera.

It is obvious that *Biglobigerinella* Lalicker, a stage attained by two different gentes, cannot have any real taxonomic significance. In addition, *Praeglobotruncana*, *Planomalina*, and several other genera, such as *Biticinella*, *Ticinella*, and *Hedbergina*, are nothing more than transitional stages in the development of some planktonic groups of foraminifera. All of these "genera" should be suppressed, for they have no boundaries. We should speak of *Globigerina caseyi* in the trochoidal stage, in the planispiral stage, and in the stage with two final apertures, ending its developmental history with the closing of these apertures by two chambers. (Mention should be made here of the incorrect indication by Bolli, Loeblich, and Tappan of "supplementary relict apertures" at the sides of their *Planomalina*. The course of their development shows that these apertures are neither supplementary nor relict; they are the more lateral parts of the aperture, and had just recently been developed by the biological entity, so that they are by no means relics.) We should also speak of the *Globigerina aspera* gens, running from trochoidal types through planispiral forms into a form with two lateral apertures and here again ending its phyletic history with the closing of these apertures by two chambers. In both cases, the doubling of the aperture is effected by the closing of the central part of the aperture by a lip which reaches a former chamber wall. In the same way, in the Tertiary, the so-called sutural apertures are formed in those developmental series that extend to the artificial genus *Globigerinoides*.

The first form in the developmental sequence of the *Globigerina caseyi* gens, a true "*Praeglobotruncana*," is found throughout the entire Albian section studied, and at its top develops into another series of forms by distinctly widening its ventral umbilical hollow. It then acquires the characters of *Globigerina stefani* Gandolfi, and can be followed in the well section up to about 100 meters above the base of the series of cores. It becomes increasingly stouter in the Cenomanian and Turonian, usually having seven chambers in the last-formed whorl. Below the level of the Coniacian, the aperture is a ventral slit at the suture; in the Coniacian and lower Santonian it becomes more and more equatorial (marginal). The ventral umbilical hollow widens more and more until, in the lower and upper Campanian, the central parts of both sides are equally hollow. Together with this evolution from "*Praeglobotruncana*" into "*Globigerinella*," which becomes total in the Maestrichtian, the surface of the test gradually becomes rougher, as is typical for *Globigerina ("Globigerinella") aspera* (Ehrenberg). I described this phenomenon previously in 1957. During the Maestrichtian, the equatorial aperture changes from a low slit into an arched opening. At the end of the Maestrichtian, the aperture frequently may develop a kind of flap on its

marginal part, which, when it reaches the surface of a former chamber, changes the aperture into two openings, situated farther laterally. With the latter development, the stage of "*Biglobigerinella*" is once more reached, this time in the upper Maestrichtian. I described this form from the Netherlands and Belgium as *Globigerina biforaminata* Hofker; it is characteristic of the *Pseudotextularia* zone of the upper Maestrichtian of the Netherlands, northwestern Germany, and Denmark.

A third developmental series apparently began in the Lower Tertiary; here we find forms such as *Globigerina pseudobulloides* Plummer, not differing in their main characters from "*Praeglobotruncana*" of the Albian or Cenomanian. Through such forms as *Globorotalia mayeri* Cushman and Ellisor or *Globorotalia opima opima* Bolli and similar Oligocene forms, Miocene forms beginning to resemble the Recent *Globigerina aequi-* *lateralis* Brady were developed. In the Miocene these forms generally had a slitlike aperture, which widened during the Pliocene into the broad, open aperture of Recent forms. Moreover, during the Tertiary, the diameter of the pores gradually increased in this series of forms or artificial species. In Recent samples from the Caribbean, we often find forms of *Globigerina aequi- lateralis* with very broad chambers, in which the equatorial part of the apertural rim shows a tendency to bend down toward a former chamber wall. This again may indicate development toward "*Biglobigerinella*," although in this line that stage has not yet been reached. In the Pacific area, a similar developmental series seems to exist, reaching at its end a form called *Globigerina* ("*Globigerinella*") *involuta* Cushman. The author has shown (1956, p. 224) that *Globigerina aequilateralis* from the Caribbean is a form quite different from *Globigerina involuta* from the Pacific.

EXPLANATION OF PLATES

PLATE 1

Figures 1–13 show the development of the *Globigerina caseyi* (Bolli, Loeblich, and Tappan) gens through 60 meters of Albian clays in a well in the Netherlands; figures 14–17 show the development of the *Globigerina aspera* (Ehrenberg) gens in the upper Albian to upper Maestrichtian. All figures × 85.

1–2   Two specimens seen from three sides, from a sample at the base of the section studied, showing the flattened trochoid test with interiomarginal aperture and covering flap.

3–4   Two specimens from a sample 20 meters higher in the section; the dorsal side shows all chambers but is somewhat depressed; the aperture is migrating toward the margin, and earlier apertural flaps remain near the ventral umbilical hollow.

5–6   Two specimens from 5 meters still higher in the section, seen from three sides; with marginal apertures, but a true umbilicus occurs only on the ventral side, while on the dorsal side the chambers of the last-formed whorl overlap the previous whorls more and more. On the ventral side, the poreless apertural covering flaps curve distinctly backward.

7   Specimen from 40 meters above the base of the section; the aperture is wholly marginal, with two lateral extensions running down the two sides of the test; on the true ventral side, the apertural flaps are stronger than on the "dorsal" side; here the central chambers are no longer visible.

8–12   Specimens from 45 meters above the base of the section. The specimens shown in figures 8 and 10 have all the characters of "*Praeglobotruncana*"; the specimen shown in figure 9 is small, with strongly overlapping chambers, especially on the "dorsal" side; those in figures 11–12 show the double aperture of "*Biglobigerinella*."

13   Specimen from 60 meters above the base of the section studied; here two chambers have been formed from the two apertures, and the end stage (the "*Biglobigerinella*" type) is reached.

14   First stage of development of *Globigerina stefani* Gandolfi, from the upper Albian at the top of the 60-meter section of Albian clay analyzed in this paper.

15   The same form from 80 meters above the base of the Albian section studied.

16   Specimen from 610 meters in a well at Ermlichheim, northwestern Germany; Cenomanian.

17   Specimen from sample 17, Lengerich well no. 2, northwestern Germany; Turonian.

PLATE 2

Figures 18–29 show the development of the *Globigerina aspera* (Ehrenberg) gens in the upper Albian to upper Maestrichtian; figures 30–35 demonstrate the gradual change from a trochoid test to a planispiral test. Figures 18–29 × 85; 30–35 × 480.

18   The first form in which the aperture begins to migrate toward the margin, but otherwise with trochoid test; from 124 meters in a shaft at Ickern, Germany; Coniacian.

19   Only slightly asymmetrical specimen, from 693 meters in Lehrte well no. 11; Santonian.

20   Specimen from Blumenauerstrasse, Hannover, Germany; lower Campanian. Here the aperture is equatorial for the first time.

21   Specimen from a quarry at Hallembaye, northeastern Belgium; Hofker sample 216, upper Campanian. The equatorial aperture remains small.

22   Specimen from a quarry at Lüneburg am Zeltberg, Germany; Hiltermann sample 5, upper Campanian.

23   Specimen from the Craie de Spiennes, near Harmignies, southern Belgium; lowermost Maestrichtian. The aperture has become larger and broader.

24   Specimen from Lüneburg am Zeltberg, Germany; Hiltermann sample 7, lower Maestrichtian.

25   Typical specimen with an equatorial aperture of the *Globigerinella* form, from 387 meters in Gross-Hehlen well no. 1016, near Hannover, Germany; lower Maestrichtian.

26   Specimen with a large equatorial aperture from an outcrop at Mesch, South Limburg, Netherlands; lowermost upper Maestrichtian.

27   Specimen of the *Globigerina aspera* type, with a very large aperture, from Kjolby Gaard, Jutland, Denmark; *Pseudotextularia* zone, uppermost upper Maestrichtian.

28   The *Biglobigerinella* type, *Globigerina biforaminata* Hofker, from Petit Lanaye, northeastern Belgium; uppermost Maestrichtian.

29   Specimen from a quarry at North, northeastern Belgium; uppermost Maestrichtian (top of Cr4). Last-formed chamber very broad.

30   Transverse section of the "*Praeglobotruncana*" form at the base of the 60-meter section of Albian clays in the well studied.

31   Specimen from 20 meters above the base of the Albian clay; the chambers are beginning to overlap the dorsal side; umbilical apertural openings are found only on the ventral side.

32   The "*Planomalina*" stage, reached at 40 meters above the base of the section studied. Typically planispiral, with apertures on both sides and the septal foramen equatorial.

33   Trochoidal specimen from 124 meters in a shaft at Ickern, Germany; Coniacian. Such specimens, leading toward the *Globigerina aspera* gens, developed from forms similar to that shown in figure 30, at the top of the Albian section.

34   Specimen from 693 meters in Lehrte well no. 11; Santonian. Again the chambers are beginning to overlap the dorsal side, but the umbilical apertures remain on the ventral side.

35   Planispiral specimen with narrow umbilical apertures on both sides, the "*Globigerinella*" type of *Globigerina aspera*; from a quarry at Lüneburg am Zeltberg, Germany; Hiltermann sample 8, lower Maestrichtian.
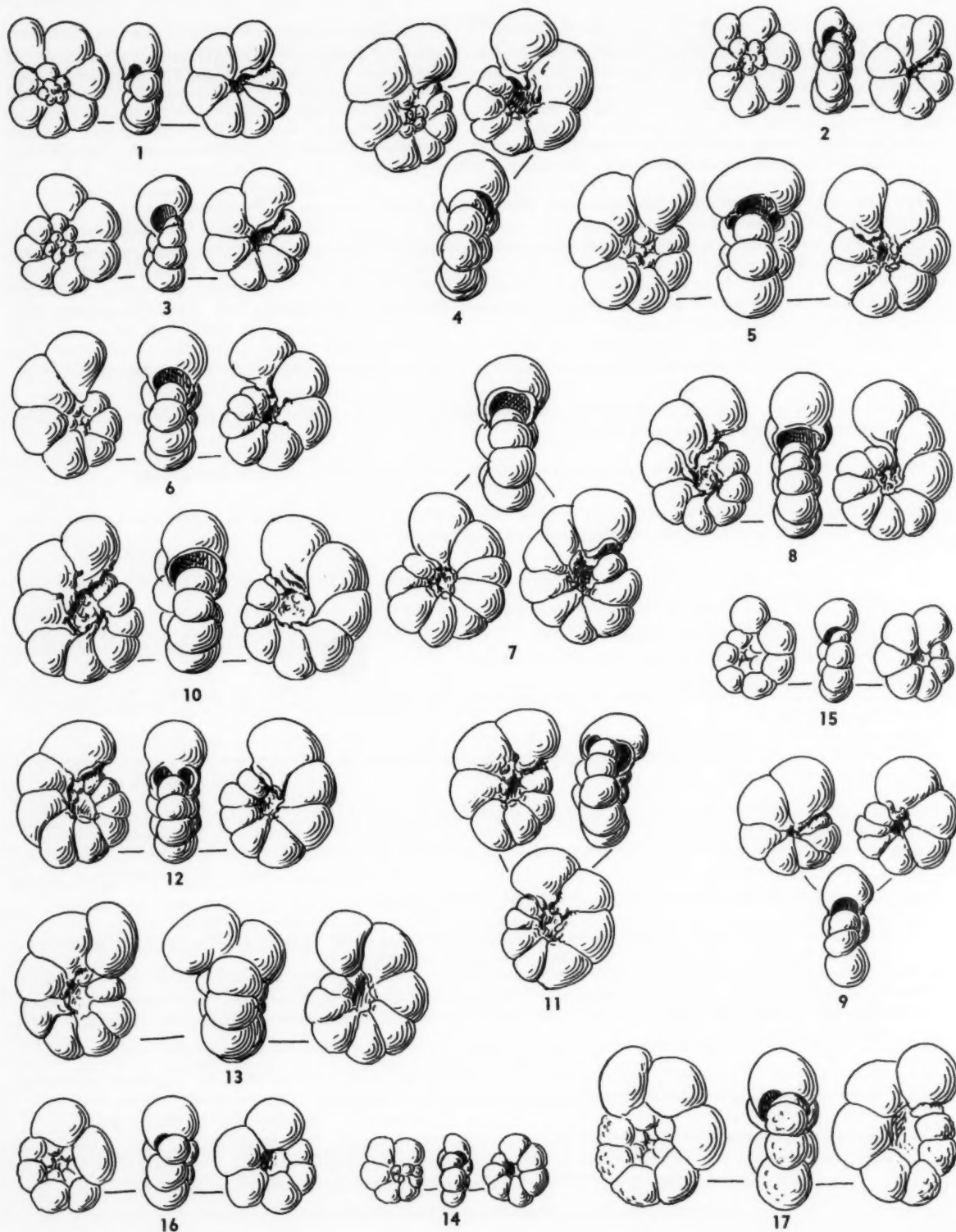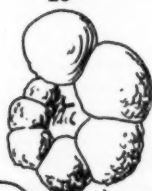
CONCLUSIONS
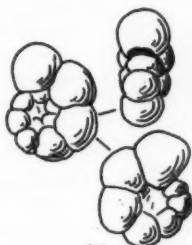
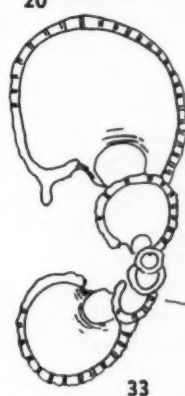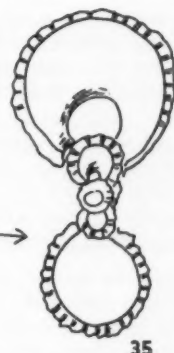There are at least three developmental series of globigerines that begin with a stage having the characters of *"Praeglobotruncana"* or, in the Tertiary, of *"Globorotalia"* without a marginal keel. In the present paper, one series is traced within the Albian, a second from the upper Albian and Cenomanian through the Upper Cretaceous to the upper Maestrichtian, and a third from the Paleocene or Danian to the Recent (see text-fig. 1).

In all three developmental series, the trochoidal characters of the *"Praeglobotruncana"* stage evolve into the characters of *"Biglobigerinella"* through a stage which has been called *"Globigerinella"* or *"Planomalina."* This is reached by the dorsal side becoming enveloped by the later whorls, and by the test gradually becoming planispiral and the ventral sutural aperture migrating to become more and more equatorial. At the end of each developmental series, there is a tendency for the last-formed chambers to become broader, resulting in the formation of a central flange on the apertural rim, which reaches the marginal wall of previous chambers, ending in the development of two apertures in the last-formed chamber. This condition may give rise to the formation of two final chambers *("Biglobigerinella")*.

The middle stage of this developmental series in the Lower Cretaceous has been given generic status as *"Planomalina."*

In reality, all forms encountered in a single developmental series form a single biological unit, one form passing gradually into the next. Since it is impossible to define the exact boundaries between two successive forms, each developmental series constitutes a "gens" in the sense of Vaughan (1905). Not only the different "genera" that are passed through during the evolution of such a developmental series (gens), but also all the "species" distinguished by previous authors, must be regarded as artificial.

There are no indications that any of the forms passed through during the evolution of a gens gave rise to a new group of forms by means of mutation. It seems quite unlikely, for example, that *"Praeglobotruncana"* gave rise to *Globotruncana*, or that *"Planomalina"* was the ancestor of *Globorotalia*. Such intermediate forms seem to represent the intermediate stages in the development of planispiral forms of the globigerines. No species of

Rotalipora can be the evolutionary descendant of a *"Planomalina."*

Close study of continuous sections shows that these developmental lines form typical orthogenetic series, running in a straight line from the first stage to the end stage of the gens. Thus, such series may be of great value in geologic chronology.

Praeglobotruncana, Planomalina, Globigerinella, and *Biglobigerinella* have no biological significance as genera; they are merely transitional stages in several developmental series, and have been repeated in different geologic periods. *Globigerinella* and *Biglobigerinella* are always the end stages of those developmental series of globigerines in which a primitive form evolved into a planispiral one. Other examples of such end stages, reached during the development of different groups, are *Loxostoma* and *Rectobolivina* among the bolivines, and *Pyramidina* in the *Reussella* group (Hofker, 1951, 1957). Such generic names are invalid because the forms have no significance as genera.

REFERENCES

BERMUDEZ, P. J.
    1952 – *Estudio de los foraminiferos rotaliformes*. Venezuela, Minist. Minas e Hidrocarb., Bol. Geol., vol. 2, pp. 52–53.

BOLLI, H. M., LOEBLICH A. R., JR., AND TAPPAN, H.
    1957 – *Planktonic foraminiferal families Hantkeninidae, Orbulinidae, Globorotaliidae, and Globotruncanidae. In: Studies in foraminifera; Pt. 1 – Planktonic foraminifera.* U. S. Nat. Mus., Bull. 215, pp. 21–50.

HOFKER, J.
    1951 – *Foraminifera of the Siboga-Expedition; Part III.* Siboga-Exped., Repts., no. 4b, pp. 45–47.
    1956 – *Foraminifera dentata etc.* Copenhagen, Univ., Mus. Zool., Spolia, no. 15, p. 224.
    1957 – *Foraminiferen der Oberkreide von Nordwestdeutschland und Holland.* Geol. Jahrb., Beiheft no. 27, pp. 414–418.

SIGAL, J.
    1956a *Notes micropaléontologiques nord-africains.* Soc. Géol. France, C. R. Somm., no. 3, pp. 35–37.
    1956b *Notes micropaléontologiques malgaches.* Ibid., pp. 210–214.
    1958 – *Les foraminifères du Crétacé inférieur vacontien.* Ibid., pp. 124–126.

VAUGHAN, A.
    1905 – *On the paleontological sequence in the Bristol area.* Geol. Soc. London, Quart. Jour., vol. 61.

ABSTRACT: *The presence of* Choffatella decipiens *in the "Toco beds" of Trinidad is discussed, and the sole occurrence of the species in that area is found to be within the Tompire formation.*

The occurrence of Choffatella decipiens in Trinidad

K. W. BARR

Texaco Trinidad, Inc.
Pointe-a-Pierre, Trinidad, W. I.

In 1956 Maync reported the occurrence of *Choffatella decipiens* from the Toco district of northeastern Trinidad (Maync, 1956, p. 92). This foraminifer was discovered by the writer during field mapping done during 1953 to 1956. Subsequently, Dr. Maync visited Trinidad, confirmed the identification of *C. decipiens*, and recorded the occurrence in the note referred to above. He stated *inter alia* that, "A fauna containing, among others, the ammonite genera *Pulchellia*, *Karstenia*, *?Nicklesia*, etc., was recently discovered in the Toco area, Northern Range of Trinidad, B.W.I. (Kugler, 1953). This fauna is dated as Barremian (Imlay, 1954). Through the courtesy of Drs. H. G. Kugler and H. Bolli, Trinidad Leaseholds Limited, the writer was recently enabled to identify numerous specimens of *Choffatella decipiens* in these Toco beds."

Unfortunately, the general phrase "in these Toco beds" has been subsequently interpreted as referring to the Toco formation, *sensu stricto*. It is, therefore, desirable to clarify the situation in regard to the stratigraphic position of these *Choffatella*-bearing beds in the Toco district.

The beds in question occur in a series of slightly metamorphosed phyllitic shales, which appear to overlie normally the low grade, partly calcareous phyllites in which the small ammonite fauna described by Imlay (1954) was found, and which are considered to be of probable lower Barremian age. Despite extensive sampling, *Choffatella* has not, so far, been found in the beds containing the ammonites. Both the ammonite-bearing beds and the overlying beds with *Choffatella* have been mapped as a single unit and designated as the "Tompire formation." Although field relationships are somewhat obscure, due to structural complications and the paucity of exposures, the Tompire formation is thought to underlie the Toco formation. Repeated sampling of the Toco formation at the type locality at Toco Bay (Trechmann and Thomas, 1935) and elsewhere has failed to reveal the presence of *Choffatella*.

It can, therefore, be positively stated that, so far, *Choffatella decipiens* has not been found either in the ammonite-bearing beds of the lower part of the Tompire formation or in the Toco formation itself. Unfortunately, Bartenstein, Bettenstaedt, and Bolli (1957) in their excellent paper on the lower Cretaceous benthonic foraminifera of Trinidad have also associated *Choffatella* with the Toco formation (*op. cit.* pages 11, 59). The implications of this erroneous association should therefore be disregarded. However, the close stratigraphic relationship between these formations is indicated by the occurrence of the foraminifer *Trocholina infragranulata* Noth in both the Toco formation, *sensu stricto*, and in the ammonite-bearing lower part of the Tompire formation. In view of this it is curious to note that *Trocholina infragranulata* has not been found in the intervening *Choffatella*-bearing beds.

The close association of the *Choffatella*-bearing beds with those containing the Barremian ammonite fauna would imply no very significant difference in age.

The stratigraphic relationships of these formations will be dealt with more completely in a forthcoming paper on the geology of the Toco district, but in the meantime it seems desirable to attempt some clarification of the position of the *Choffatella*-bearing beds in view of the widespread occurrence of this fossil in the lower Cretaceous of northern South America.

REFERENCES

BARTENSTEIN, H., BETTENSTAEDT, F., AND BOLLI, H. M.
   1957 – *Die Foraminiferen der Unterkreide von Trinidad, B.W.I.* Eclogae Geol. Helv., vol. 50, no. 1, pp. 5–67, pls. 1–8, tfs. 1–3.

IMLAY, R. W.
   1954 – *Barremian ammonites from Trinidad, B.W.I.* Jour. Pal., vol. 28, no. 5, pp. 662–667, pls. 74–75.

KUGLER, H. G.
   1953 – *Jurassic to recent sedimentary environments in Trinidad.* Assoc. Suisse Geol. Ing. Petrol., Bull., vol. 20. no. 59, pp. 27–60, tfs. 2.

MAYNC, W.
   1956 – *On the age of Choffatella-bearing beds in Venezuela.* Micropaleontology, vol. 2, no. 1, p. 92.

TRECHMANN, C. T., AND THOMAS, H. D.
   1935 – *Fossils from the Northern Range of Trinidad.* Geol. Mag. vol. 72, pp. 166–175.

ABSTRACT: *Construction and operational details of a machine for separating fine organic and inorganic debris from palynomorph preparations are described.*

"Vibraflute"

ROBERT H. TSCHUDY
Palynological Research Laboratory
Jamestown, Colorado

The "Vibraflute" is a device for separating inorganic and fine organic debris from pollen and spore preparations. All samples treated have been very well cleaned. Moreover, in the most favorable instances, there has been a one hundred fold concentration of microfossils.

The device is shown on the accompanying drawing. It consists of a glass tube (A), 24 inches long and $\frac{1}{2}$ inch inside diameter, closed at one end. The tube is straight except for a $3\frac{1}{2}$ to 5 degree gradual bend 3 or 4 inches from the closed end. One-half inch holes, spaced approximately $1\frac{1}{2}$ inches apart, are located along the top of the tube. There is a lip (K) on the open end. The tube, with the open end at the right, is mounted on aluminum channel (H) and held in place by two spring clamps (G). The aluminum channel is hinged (B) to the wooden base at the left end and the other end is supported by a $\frac{1}{4} \times 3$ inch screw (J), attached to the wooden frame at the right end. The screw raises and lowers the channel and the glass flute.

Vibration is accomplished by means of a Burgess Vibro-Graver with a round-tipped insert. The Vibro-Graver is attached in a vertical position, against the wooden frame at the left end, by means of a heavy rubber band (D). The vibrator tip (C) of the Vibro-Graver is in contact with the under surface of the aluminum channel at the left end. Under the Vibro-Graver is a supporting spring (E) which assures constant pressure of the vibrator tip against the aluminum channel.

OPERATION

With the elevator screw (J) raised so that the right end of the tube is approximately $1\frac{1}{2}$ inches above the horizontal, the sample is placed in the first hole at the closed end of the tube; thus the sample remains near the closed end. The Vibro-Graver is connected to an electric outlet and after the switch is turned on water is added through the hole at far left by means of a 250 ml. polyethylene wash bottle provided with a small diameter outlet tube. Water is added slowly and at the same time the elevator screw is lowered slowly. The lighter, smaller particles are kept in suspension by the vibration and are carried down the tube by the water which is being continually added. The heavier, larger particles tend to settle immediately at the left end of the tube. As the tube approaches the horizontal the sample is spread along the complete length of the tube. When the tube is lowered, so that the right end is slightly lower than the left, the liquid containing the finest organic particles will begin to drip out of the open end. This liquid is caught in a centrifuge tube. After the machine has been in operation for two or three minutes the vibrator is turned off and the sample examined under the microscope. Water mounts are obtained by inserting a pipette into the holes along the top of the tube. The palynomorph distribution can be determined by examining four or more stations. For example, if the fossils are confined to the upper two-thirds of the tube, the residue in the lower end can be washed out by inserting the tip of the wash bottle in the appropriate hole and washing the unwanted residue out the open end of the tube. The remainder, containing the pollen and spore concentration, can then be washed into a vial for storage. If heavy mineral matter is present in the upper end of the tube, the pollen and spore fraction below this point can be washed into a vial, leaving the heavier residue in the upper part of the tube.

Should the tube be lowered too rapidly during vibration, some of the smaller pollen grains may be carried along and out of the tube with the finer debris. If this occurs the entire sample can be collected in the centrifuge tube, concentrated by centrifuging and revibrated. In some instances, when the sample volume is too great or the proportion of fine organic debris is very high, it may be profitable to put the sample through the "Vibraflute" several times in order to eliminate more of the fine debris.

It is of paramount importance to maintain the tube in a clean condition at all times. The glass tube may be removed for cleaning by merely unfastening the hold-down springs and lifting the tube. A slight amount of dirt, such as a finger print in the vicinity of the lip, may prevent the even escape of fluid and thus interfere with the separation.

It has been found advantageous to use a small amount of detergent in the wash water; even so, the organic matter may occasionally have a tendency to flocculate. This tendency can be largely overcome if a few grains
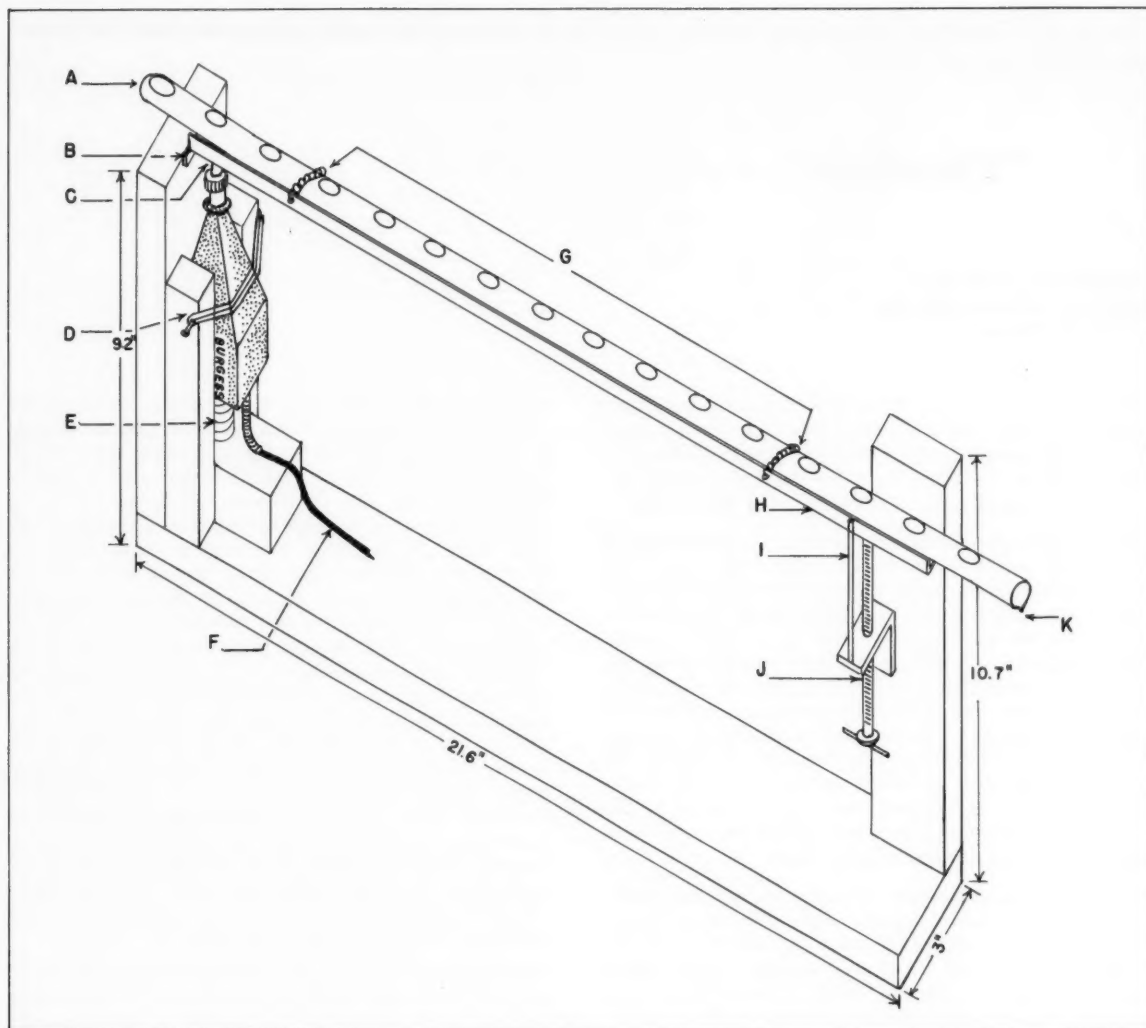
TEXT-FIGURE 1

A, glass tube 24 inches long, $\frac{1}{2}$ inch inside diameter, with $\frac{1}{8}$ inch holes on $1\frac{1}{2}$ inch centers, upper end closed and bent $3\frac{1}{2}$ degrees, 3 inches from end; B, hinge; C, round tip of Vibro-Graver in contact with channel; D, rubber band retainer; E, constant pressure spring; F, 110 V., A. C.; G, hold-down springs; H, aluminum channel; I, guide, rod; J, elevator screw; K, lip on glass tube. Scale $0.5'' = 2''$.

---

of sodium metasilicate (Metso) or a pellet of metaphosphoric acid is added to the sample before processing.

In practice, the sample is mixed thoroughly by placing it in an ultrasonic vibrator for a few moments immediately before placing the sample in the "Vibraflute." This step is helpful but not imperative. Precautions which should be observed are as follows:

1) Adjust the Vibro-Graver so that the vertical movement is at a minimum. The Vibro-Graver is provided with an adjusting screw at its base.

2) Lower the tube slowly by means of the elevator screw, meanwhile adding water slowly. One or two trials should suffice to determine the rate.

3) Do not use a large sample. If the residue is too voluminous, put it through the machine in several portions.

4) Do not bring the water level quite to the lower edge of the holes in the tube at the beginning of the operation.

5) Do not add too much detergent to the wash water as film (air) bubbles may be produced.

ABSTRACT: *A simple, rapid, and inexpensive method for concentrating pollen and spores and for cleaning other microfossils is described.*

A silica depressant method for concentrating fossil pollen and spores

BERNARD C. ARMS
Geochronology Laboratories
University of Arizona
Tucson, Arizona

In the course of extracting pollen from the various types of sediments found in the semi-arid southwest United States and Mexico, the writer has evolved a method, now in routine use at the Geochronology Laboratories, for the concentration of fossil pollen prior to other treatment. Arid land sediments may be low in pollen content and often may form an insoluble colloid when treated with hydrofluoric acid.

The following method, an adaptation of a metallurgical process, has proved quite effective, both in concentrating the pollen from low-density sediments, and in retarding colloid formation. A depressant is used to retard removal of silicates; and a chemical to coat the grains and adjust surface tension of the fluid. A method to remove the pollen is presented.

Procedure

1) Thoroughly crush dry samples. Clean surfaces of wet clays and crumble into bits. Fill a 50 ml. Nalge centrifuge tube one-fourth to one-third with sample. Add distilled water to one-half full, stir, and add the following reagents in order, stirring after each addition: 1 cc. depressant solution, 2 cc. pine oil solution, 3 cc. bubbling solution.

2) Rinse outside of the centrifuge tube (distilled H_2O and acetone) and place upright in a one-liter beaker (text-figure 1). Insert gas jet with gas emanating at a low, constant pressure. Agitate periodically, adding solutions or distilled water as required.

3) Collect bubbles in the beaker (an acetone jet will reduce the bubble volume). Bubbling time – 15 minutes. Remove sample centrifuge tube (contains cleaned material bearing other microfossils – foraminifera,

ostracodes, etc., if present) from beaker. Wash, dry and examine this fraction. Swirl contents of beaker, adding distilled water as required and decant pollen-bearing solution into clean Nalge centrifuge tube. Centrifuge at high speed and discard decants. Residue in Nalge tube is the pollen concentrate (pollen, spores, hystrichospherids, if present). Wash the pollen concentrate twice with distilled water, centrifuge, and proceed with normal laboratory extraction technique. Wash, dry, and examine residue in beaker for presence of other microfossils.

Reagents

Depressant solution – 5% solution *water-soluble* chemical Quebracho in distilled water.

Surface tension adjustor – 5% solution of pine oil in distilled water (shake vigorously before addition).

Bubble solution – concentrated solution of laboratory detergent in distilled water.

Remarks

Nalge centrifuge tubes are specified as they will stand boiling water baths, are acid resistant, and not subject to breakage.

The gas jet may be a pipette, glass or metal tube with appropriate orifices. The source of the gas may be the breath, domestic gas, bottled carbon dioxide, or filtered compressed air at *very low, constant pressure*. This laboratory uses a pressure chamber with individual outlets permitting concentration of several samples simultaneously.

TO GAS SOURCE
INJECTOR
STIR ROD
1 LITER BEAKER
NALGE TUBE WITH SAMPLE
POLLEN BEARING BUBBLES
POLLEN CONCENTRATE

PLUG
4 OPPOSED $\frac{1}{16}$" HOLES
$\frac{1}{8}$"
10"
2"

NOT TO SCALE

NOTE: TUBING POLISHED STAINLESS STEEL $\frac{1}{2}$" O.D. x $\frac{3}{64}$" t.
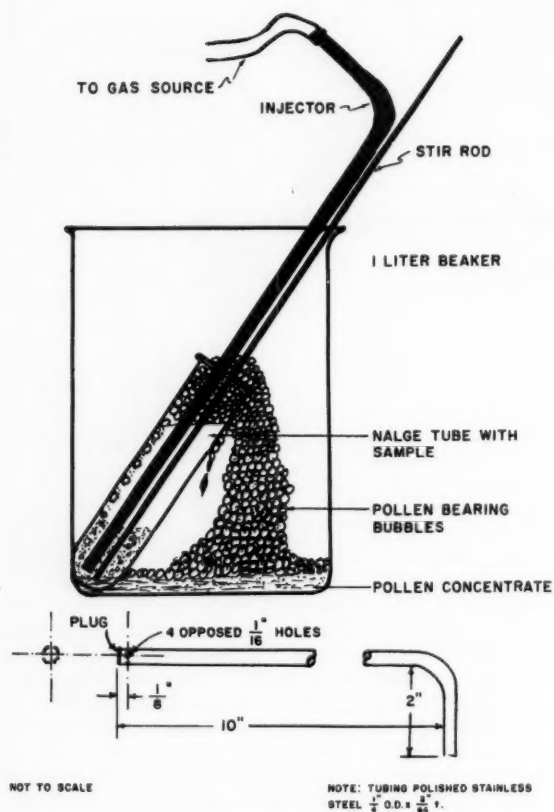
TEXT-FIGURE 1

Advantages are threefold:

1) Concentration is simple, inexpensive, not time consuming.

2) Concentration reduces time and cost of subsequent extraction and is used with known techniques.

3) Concentration is an excellent method for cleaning other microfossils in the sediment being analysed.

I wish to acknowledge the assistance provided by J. C. Mostert, P. S. Martin, J. Gray, and J. Schoenwetter.

Contribution No. 19, Program in Geochronology, University of Arizona, Tucson.

BIBLIOGRAPHY

FAEGRI, K., AND IVERSEN, J.
  1950 – *Text-Book of modern pollen analysis*. Ejnar Munksgaard, Copenhagen, 168 pp., illus.

FREY, D. G.
  1955 – *A differential flotation technique for recovering microfossils from inorganic sediments*. New Phytologist, vol. 54, no. 2, pp. 257–258.

FUNKHOUSER, J. W., AND EVITT, W. R.
  1959 – *Preparation techniques for acid-insoluble microfossils*. Micropaleontology, vol. 5, no. 3, pp. 369–375, text-figs. 1–2.

ABSTRACT: *A comprehensive set of palynological techniques usable for extracting representative fossil assemblages from different lithologies is presented.*

Palynological techniques for sediments

F. L. STAPLIN, S. J. POCOCK, J. JANSONIUS, AND E. M. OLIPHANT
Imperial Oil Limited
Calgary, Alberta

Some of the techniques used by commercial palynological laboratories have been presented by Tschudy (1958), Jeffords and Jones (1959) and Funkhouser and Evitt (1959). Methods that have been proven in our laboratory, including new procedures, are described in this paper.

A comprehensive knowledge of techniques is necessary for the palynologist, as no single technique is effective for the extraction of representative fossil assemblages from all lithologic types. The extracted assemblage that has been subjected to the least laboratory-inflicted damage is the most likely to be representative of the material preserved in the sediments. The greatest care must be taken with samples from which statistical data are desired. Slight variations in techniques often produce surprising variations in the relative number of species.

Before disintegration procedures are applied, the rock sample should be examined carefully. The relative amounts of organic, calcareous, gypsiferous and pyritic material, as well as the texture and cementation, should be noted and considered in planning the order of the procedures to be followed. Layers or laminae of unfavourable constitution may be removed mechanically before the sample is processed, "high-grading" the yield and simplifying chemical procedures.

Physical disintegration prior to chemical treatment

This procedure is applied to most non-cemented materials, particularly claystones and siltstones, but not to sandstones and some volcanic materials. Cemented rocks are placed directly in acid treatment.

1) Break sample into small pieces (pea-sized). If the sample is damp, dry at a temperature not exceeding 100° C.

2) Cover sample with a mixture of 75% Soltrol C (core analysis fluid, Phillips Petroleum Corp., Bartlesville, Oklahoma) and 25% dispersive liquid household detergent such as liquid Vel. Commercial dispersive detergents, such as Polytergent J–400 (Mathieson

Chemical Corp., New York) perhaps are better, and may be used in a concentration of 5–10 per cent, with the Soltrol C. Not all detergents are miscible with Soltrol C, and some are floculative.

2a) Optional: Add a 1:1 mixture of acetone and benzene (increases the effectiveness of the method in some cases).

3) Allow to stand, preferably overnight. Agitation is helpful, but not necessary.

4) Pour off mixture. Add boiling water and agitate the sample. The sample usually separates into small particles.

5) Transfer sediment to 100 ml. centrifuge tube and wash until clean, short-centrifuging (Funkhouser and Evitt, 1959) to remove finely divided material. The rate and time depend on the equipment and the operator's technique. Very dilute detergent may be added to promote dispersal of very fine particles.

In rare cases, the residue may be broken down sufficiently to render chemical treatments unnecessary, and, after adequate washing, is subjected to heavy liquid separation. The residue may be examined for calcareous fossils at this stage. If chemical treatment is necessary, it can be accomplished in a fraction of the time (minutes rather than hours) with less wastage of chemicals and less laboratory-induced corrosion of the fossils.

Some coals may be partly solubilized in a mixture of 15 per cent methanol, 15 per cent acetone and 70 per cent benzene. This shortens the oxidant treatments.

Removal of carbonates

Sarmiento (1957) briefly described the use of orthophosphoric acid to remove carbonates. In 50 per cent solution, it is more gentle but just as rapid as a hydrochloric acid solution. HCl may render insoluble some Al, Ti, and Fe materials. Always spot-check the residue for completeness of carbonate removal before applying hydrofluoric acid. Mild heat and/or agitation may be applied by means of the Fisher oscillating hot plate

or other shaker apparatus. The residue may be examined for siliceous fossils at this stage and suitable concentration procedures applied.

Removal of silicate

Many concentrations of both technical and reagent grade HF have been recommended. All are probably satisfactory, but the relative safety of the factory container should be the primary consideration. The residue should be free of carbonate and very clean. The Fisher oscillating hot plate is a definite aid, as the heat volatilizes silicon as SiF_4. Some titanium also volatilizes as TiF_4.

Oxidation of organic matter

Oxidizing agents act on organic substances by cracking carbon chains, producing a step-by-step conversion to the oxidized states of simpler carbon compounds. The appearance of hydroxyl and O_2 substituents at adjacent carbon atoms enables further oxidizing attack on the remaining C–C (Holst, 1954). In the case of many oxidizing agents containing oxygen, the oxidation potential is partly a function of the hydrogen ion concentration of the solution. Varying the pH may have pronounced effects upon the reaction. Most oxidants (electron acceptors) such as nascent O_2, ozone, H_2O_2 (hydroxyl radicals), halogens and halogen-oxygen compounds are all useful on some substances.

With any oxidant, the differential destructions of spores, pollen and cuticles may become a problem that can be minimized only by the most careful conduct of the procedure. A wise precaution is to prepare a few slides for comparative purposes about midway in the process.

Oxidation of unwanted organic matter is usually accomplished by means of Schulz' reagent (30 gm. $KClO_3$, 300 ml. H_2O, 600 ml. concentrated HNO_3). The Raistrick or dry Schulz' method, long used in England (Raistrick, 1934; Raistrick and Marshall, 1939), often yields better results in a much shorter period of time. Two grams of coal or coaly residue and two grams of granular $KClO_3$ are mixed in a small beaker with sufficient water to dampen the mixture (the water present in the residue from previous processing is usually sufficient). Ten ml. of concentrated HNO_3 are added, very slowly in order to prevent overheating. The water is necessary to prevent combustion or explosion when the HNO_3 is added to the mixture. On some coals the water can be omitted, following the English method exactly, and a more pronounced reaction obtained. Results are comparable to those obtained with the toxic chromic anhydride-nitric acid solution (Funkhouser and Evitt, 1959).

Gentle heating of the Schulz' reagent, following either of the above methods, greatly increases oxidation of the carbonaceous matter, and may be useful on residues from slightly metamorphosed rocks. The treatments should be spot-checked frequently. An aqueous solution of 10 per cent nitric acid and 10 per cent chromic anhydride has proved useful in isolating cells of lignified tissues (Wallis, 1957). A solution of potassium permanganate in sulfuric acid yields results seemingly comparable to those of Schulz' solution, but an extra step for decolorization is necessary. Various dilutions of chromic anhydride and sulfuric acid have not yet been tested, but should be less corrosive than nitric acid solutions.

One part 10 per cent hydrogen peroxide mixed with one part 5 per cent KOH solution is often useful, following acetolysis of Recent pollen, as well as on fossil specimens, following Schulz' solution. Its bleaching and oxidizing action (carefully watched under the microscope) can be carried to any desired degree, including separation of the wall layers, bypassing the process of chlorination. It has worked on dark-hued pollen, spores and chitinozoa. The process should be carried out in 100 ml. tubes or beakers so that the action can be stopped by dilution and washing at the desired point. Practice is needed to obtain best results with this method, and it is wise to use only a portion of the residue.

Agents remaining to be tested thoroughly include ceric sulfate and potassium bromate (both in acid medium), calcium hypobromite, calcium hypochlorite and chlorohypochlorite (all in neutral or alkaline medium). Sodium chlorite is commonly used in fiber industries if destruction of cellulose is to be avoided. Lignin is commonly oxidized in the textile and jute fiber industry by successive treatment with hypochlorite and alkaline peroxide solution (the hypochlorite must not enter the alkaline peroxide bath or the fibers will be attacked).

Solubilizing oxidized humic materials

Five per cent potassium carbonate (K_2CO_3) solution is used in our laboratory to solubilize oxidized material, in place of hydroxides or solvents. It may be applied directly to weathered materials not requiring oxidants.

This reagent has the following important advantages:

A) Separation of fossils from unwanted organic material is more rapid and complete.

B) The action of the reagent is more gentle, leaving the fossils less corroded.

C) Residues wash clean more rapidly.

Heavy liquid separation

Zinc bromide in HCl-acidified aqueous solution yields excellent separations of acid-insoluble fossils from residues. It has the following advantages over zinc chloride:

A) Much lower viscosity allows more rapid and clearcut separations.

B) The solution seems to be more stable.

Zinc bromide is dissolved in 10 per cent HCl until the concentration point is approached. The specific gravity is adjusted as desired by means of distilled water and a

hydrometer (approximately 2.0 in our laboratory). Acidification is necessary to prevent precipitation of water-insoluble zinc hydroxide (no less a problem if zinc chloride is used). The procedure, usually carried out in a 100 ml. centrifuge tube, is as follows:

1) Acidify the residue with weak HCl. Pour off liquid after centrifuging.

2) To the moist acidified residue, add sufficient zinc bromide solution to permit a good separation. Mix well.

3) Centrifuge at about 700 rpm (remember to balance for the heavy solution). In some cases, normal settling is superior to centrifuging.

4) Pipette the light fraction into a separate tube with a suction bulb (a small 15 ml. round-bottom tube, if the amount is very small, but a large tube facilitates washing).

5) Add water acidified with HCl (about 10 per cent) and centrifuge. Repeat dilution and centrifuging at least once. Wash clean with water. Short-centrifuge if necessary.

In some cases, due to attached mineral matter, many fossils may remain with the heavy portion, therefore it is not wise to discard the heavy portion without careful examination. The specific gravity of the heavy liquid sometimes must be adjusted to the specific sample, and the separation repeated. It is possible to reclaim part of the zinc bromide. Zinc bromide is toxic, but with normal laboratory precautions, is much safer than the usual organic heavy liquids. In order to circumvent the rather tedious pipetting, some experimentation will be carried out with thin plastic sleeves, closed at one end and having an outer diameter about equal to the inner diameter of the centrifuge tube. The sleeve is removed from the tube, constricted below the light fractions and the light fractions washed into another tube.

Permanent mounting of fossils

A modification of Article 10 of the International Code of Botanical Nomenclature accepted by the Ninth International Botanical Congress (Montreal, 1959)

makes mandatory the preservation of fossil type specimens. A figure or a description can no longer serve as the type. Adoption of the hard mounting media recommended by Jeffords and Jones, Wilson (1959), and Funkhouser and Evitt is strongly urged. The mount must be thin enough to permit the use of oil immersion objectives. Number 0 cover slips, available from Clay-Adams Co. of New York, and other sources, are most suitable. Type slides should be examined periodically and repaired in case of deterioration.

REFERENCES

FUNKHOUSER, J. W., AND EVITT, W. R.
1959 – *Preparation techniques for acid-insoluble microfossils.* Micropaleontology, vol. 5, no. 3, pp. 369–375, text-figs. 1–2.

HOLST, G.
1954 – *The chemistry of bleaching and oxidizing agents.* Chemical Reviews, vol. 54, pp. 169–194.

JEFFORDS, R. M., AND JONES, D. H.
1959 – *Preparation of slides for spores and other microfossils.* Jour. Pal., vol. 33, no. 2, pp. 344–347, text-fig. 1.

RAISTRICK, A.
1934 – *The correlation of coal seams by microscope content. Part I. – The seams of Northumberland.* Inst. Min. Eng., Trans., vol. 88, no. 3, pp. 142–153.

RAISTRICK, A., AND MARSHALL, C. E.
1939 – *The nature and origin of coal and coal seams.* London: The English Universities Press Ltd., 282 pp.

SARMIENTO, R.
1957 – *Microfossil zonation of Mancos group.* Amer. Assoc. Petrol Geol., Bull., vol. 41, pp. 1683–1693, pl. 1, text-figs. 1–4.

TSCHUDY, R. H.
1958 – *A modification of the Schulze digestion method of possible value in studying oxidized coals.* Grana Palynologica, n. s., vol. 1, no. 3, pp. 34–38.

WALLIS, T. E.
1957 – *Analytical microscopy.* London: Churchill, Ltd., 2nd ed.

WILSON, L. R.
1959 – *A water-miscible mountant for palynology.* Oklahoma Geol. Survey, Geol. Notes, vol. 19, no. 5, pp. 110–111.

BENELUX

J. H. VAN VOORTHUYSEN

BELGIUM
University of Louvain, Coal Museum

Dom Remacle Rome, O.S.B., Director of the Paleontological Museum of the University of Louvain, together with Abbé J. Goreux, have in press a manuscript on the ostracode genus *Cryptophyllus*. He is also studying the rich ostracode fauna of the Pliocene of the Antwerp Crags.

University of Louvain, Geological Institute

Prof. Lecompte and his pupils have in progress a micropaleontological research study on the Devonian sediments. The results are not yet ready for publication. Prof. Gullentops informs me that there has recently been established a Flemish chair of paleontology, with Professor Boné in charge. He expects, therefore, that there will soon be micropaleontological activity to report.

Royal Belgian Institute of Natural Sciences Botanical Section

Dr. R. Vanhoorne will publish this year a palynological study of the Pleistocene of Belgium. Further, he hopes to publish, in the near future, the results of a palynological study on the Holocene soils of Belgium. Finally, there will appear this year in the Natuurwetenschappelijk Tijdschrift a contribution on the interglacial peat at Lo, Belgium.

Royal Belgian Institute of Natural Sciences Centre National de Géologie Houillère

The Association for the Study of Carboniferous Stratigraphy, which your correspondent mentioned in his former news report, has been discontinued. The activity has been reestablished under the name indicated in the heading. The work of this national center of Carboniferous geology has also been enlarged.

Faculté Polytechnique de Mons Departement de Géologie

Professor René Marlière is still at work on the study of the ostracodes of the Montian.

NETHERLANDS
University of Leiden State Museum of Geology and Mineralogy

Professor van der Vlerk, Director of the Museum, published three papers in 1959. The first of these is a paper, with T. F. Grimsdale, entitled "A review of some subgeneric nomenclature among the *Lepidocyclinae*" (Tertiary orbitoidal foraminifera) which appeared in Kon. Ned. Akademie van Wetenschappen-Amsterdam, Proceedings, series B, vol. 62, no. 1. The second paper issued is entitled "Orthogenese en Orthoselectie" (ibid., Verslag van de gewone vergadering der Afd. Natuurkunde, vol. 68, no. 7); and the third is on the "Problems and principles of Tertiary and Quaternary stratigraphy" (Quart. Jour. Geol. Soc. London, vol. 115, pp. 49–64).

His research work on *Lepidocyclina* is not yet finished. In 1959 he studied the Molengraaff collection of de Vogelkop (New Guinea), the Fritz Weber collection from the the Dutch East Indies, deposited in Basel, and the collections of Douvillé and Schlumberger in Paris.

University of Leiden Paleobotanical Laboratory

Three pupils, under the leadership of Professor Florschütz, are working on peat samples from Austria, north Italy and northeastern Netherland. As Director of the government Agricultural Experimental Station at Velp, near Arnhem, he is engaged in the study of peat samples from the south of France and Spain.

University of Utrecht

Dr. Drooger, Conservator at the Geological Institute, has published the following papers: C. W. Drooger and J. Magné – Miogysinids and planktonic foraminifera of the Algerian Oligocene and Miocene (Micropaleontology, vol. 5, no. 3, 1959); C. W. Drooger and D. A. J. Batjes – Planktonic foraminifera in the Oligocene and Miocene of the North Sea Basin (Kon. Ned. Ak. v. Wet., Proceedings, series B, vol. 62, no. 3, 1959); C. W. Drooger and C. Socin – Miocene foraminifera from Rosignano, northern Italy (Micropaleontology, vol. 5, no. 4, 1959). The following papers are in press: C. W. Drooger – *Miogypsina* in northwestern Germany; J. P. H. Kaasschieter – Eocene foraminifera of Belgium; R. Felix – Quantitative studies on Miocene foraminifera of Dingden and other localities; C. W. Drooger – Description of Paleocene *Rotaliidae* of French Guiana.

Other investigations on various subjects are also being made by J. E. van Hinte. Some were completed with only unpublished reports: Recent foraminifera from Assab, with A. Bouma; Miocene foraminifera Rosignano (with J. P. de Zoete); Miocene foraminifera Philippines (with C. C. Vervloet).

University of Groningen

Professor Kuenen, Director of the Geological Institute at Groningen, has recently established a micropaleontological section, with Mr. G. J. Boekschoten in charge. He is presently engaged in setting up his laboratory. His first objective is the study of Recent and Tertiary foraminifera.

University of Amsterdam
Geological Institute

Professor MacGillavry mentioned to me that he is engaged in checking the evolution of *Lepidorbitoides minor* in the Maestrichtian by means of a succession of samples taken in direct superposition, at the cement quarry at St. Pietersberg, Netherlands. In addition, investigations are being made on the variability coefficient of characteristics in populations of larger foraminifera.

University of Amsterdam
Hugo de Vries Laboratory

Professor Heimans informs me that in the course of the year the following publications have been issued: B. Zwart and J. J. Frieswijk – Datierung des Basistorfes unter Amsterdam (Acta Botanica Neerlandica, vol. 8, pp. 356–365, 1959); J. Spoelstra – Pollenanalyse van de bodem onder Amsterdam; G. J. Bollen – Pollenanalyse van het Vragenderveen.

Geological Bureau of the Netherlands
Coal Mining District, Heerlen

Dr. S. J. Dijkstra, in charge of the Paleobotanical Section, has submitted a paper for publication to the Palaeobotanical Journal in India entitled "On megaspores, *Charaphyta* fruits and some other small fossils from the Cretaceous."

Geological Survey of the Netherlands

At the Paleobotanical Laboratory, where W. H. Zagwijn is in charge, a study has been completed on the vegetation history of the Eemian and Weichselian. A paper on this subject is in preparation. This paper will appear as a doctoral dissertation in March 1960 entitled "Aspects of the Pliocene and early Pleistocene vegetation in the Netherlands (Med. Geol. Stichting, series C). Mr. Zagwijn published, in Fortschr. Geol. Rheinl. u. Westf., vol. 4, 1959, a paper entitled "Zur stratigraphischen und pollenanalytischen Gliederung der pliozänen Ablagerungen des Roertal- und des Venloergrabens in der Niederlanden."

Mr. Zagwijn is also trying to obtain a better understanding of the vegetational history of the Netherlands middle Pleistocene, especially from the Saale (Riss) Glacial.

In addition to contribution on the benthonic diatom species of the Dollar-Eams estuary, Mr. van der Werff has also worked on planktonic species. Both contributions are in press in "Das Ems-Estuarium." He gave a preliminary report on the results at the International Limnological Congress in Austria. During the past year, Mr. van der Werff was especially interested in ecological problems. He found in Pleistocene clays, which were believed to be deposited by meltwater, a marine diatom assemblage belonging to the so-called "Holstein formation" (Mindel-Riss-Interglacial).

In connection with dike construction in the southwestern part of the Netherlands, research on diatoms was carried on in the "Biesbos," an environment of brackish to nearly freshwater, still influenced by tidal floods. Changes in the diatom flora in this environment will be studied. The second and third chart of the diatom flora of the Netherlands by van der Werff and Huls has been issued. The fourth chart will probably be issued in January 1960. The price is Hfl. 5.20 ($1.40)and not $1.30 as your correspondent incorrectly stated in his former report.

Your correspondent has nearly finished his organizational and editorial task for "Das Ems-Estuarium; ein sedimentologisches Symposium," which is now in press and will be issued in early 1960. He is also engaged in the study of the Mio-Pliocene boundary in the North Basin, and is investigating the Eocene sediments of the Netherlands.

The laboratory of Dr. Jan Hofker
The Hague

Dr. Hofker wrote me concerning his activities during the past year. They are too numerous to report in detail; therefore I am obliged to make a choice. Publications of Dr. Hofker during this year: Orthogenesen von Foraminiferen (Neues Jahrb. Geol. u. Paläont., Abh., vol. 108, no. 3, pp. 239–259, 1959). – The genera *Eponides, Lacosteina, Nuttalloides, Planorbulina* and *Halkyardia* (Cushman Found. Foram. Res., Contr., vol. 10, pt. 4, 1959). – On the splitting of *Globigerina* (Cushman Found. Foram. Res., Contr., vol. 10, pt. 1, 1959). – Les Foraminifères du Crétacé supérieur de Harmignies bassin de Mons (Ann. Soc. Géol. de Belg., vol. 82, pp. 319–333, 1958–1959). – Die Asterigerinen Foraminiferen (Pal. Zeitschr., vol. 33, no. 4, 1959). He has in press studies on an analysis of the Albian genus *Planomalina*; and an analysis of *Globigerina cretacea*.

Further, Dr. Hofker is carrying on a study on the Danian-Paleocene boundary, the foraminifera of the tidal zone of the Antilles, and the foraminifera of the Santonian, Campanian and Dordonian of the Basin of Aquitaine.

J. H. van Voorthuysen
Geological Survey of the Netherlands
Haarlem

GERMANY

HEINRICH HILTERMANN

First, let us commemorate Karl Feifel who died at the age of 86 on August 12, 1959 in Stuttgart. The deceased was an official of the administration (Amtmann) and paleontology was his hobby. He started by collecting Jurassic fossils. The identification of them brought him into contact with the "Stuttgarter Naturalien-Kabinett" and the Geological Survey. Early in his work he paid special attention to the microfauna of the Jurassic, especially echinoderms, sponges, foraminifera, and Triassic conodonts. By his very careful collecting methods and his never-ceasing efforts, he encouraged and made possible detailed scientific study by other research workers. In acknowledgement of his work, the University of Tübingen conferred upon him the title of *Dr. rer. nat. honoris causa*. We will always remember Dr. Feifel.

In my annual report entitled "Bibliography of Micropaleontology in Germany for 1958", which will be published in an early issue of this quarterly, about 100 publications are cited. Amongst them, 44 are mainly stratigraphic papers. The rest deal with special taxonomic problems: Nannoplankton–3, Dinoflagellata, Chitinozoa and other microplankton–6, Algae–2, Foraminifera–11, Holothuria–1, Bryozoa–2, Brachiopoda–1, Conodonts–6, Entomostrace–1, Ostracoda–11, and Otoliths–2. On the whole, the stratigraphic and taxonomic papers cited concern the following parts of the column: Cretaceous–24, Tertiary–23, Jurassic–19, Devonian, Carboniferous and Tertiary–11 each, Silurian–3, and Cambrian, Zechstein and Triassic–1 each. Nine percent of them deal with palynology; six per cent are concerned with technical matters.

Meanwhile, the two volumes of the excellent manual "Grundzüge der zoologischen Mikropaläontologie" by V. Pokorny (VBE Verlag der Wissenschaften Berlin) had been published. This work represents a critical review of important data on morphology, taxonomy, and ecology of all zoological fossils that are micropaleontologically important. In contrast to the manuals hitherto published on the subject of micropaleontology, there is no undue emphasis placed on any particular group. It must be noted that, for the first time, the Paleozoic ostracodes are classified with the younger forms.

The revision of the Wealden Cyprideen by J. Wolburg (Senckenbergiana Lethaea vol. 40, pp. 223–315) and the Lias ostracodes by W. Klingler, F. Neuweiler, and E. Triebel (Geol. Jahrbuch Hannover, vol. 76, pp. 335–409) resulted in other new publications. The work by Wolburg comprises all species of the genus *Cypridea* occurring along the Jurassic – Cretaceous boundary, together with a detailed account of the stratigraphic distribution and phylogenetic relationships. The three other authors described, in all, 21 new species and 2 new subspecies of the genera *Protocytheridea, Aphelocythere, Otocythere* and *Trachycythere*. E. Martini of the Geological Institute of the University of Frankfurt/M. has started an intensive investigation of the nannofossils. The results of these investigations, which emphasize stratigraphy, are condensed in a first report on discoasters (Coccolithophoridae), published in the Senckenbergiana Lethaea (vol. 40, pp. 137–157).

The significance of the conodonts described by J. Müller from the Cambrian of Europe and North America (Deutsche Geol. Ges., Zeitschr., vol. 111, pp. 434–485) extends beyond the borders of Germany. There are twenty-seven new species belonging to nine genera which serve to establish the Ordovician boundary.

Phylogenetic studies on *Gaudryina* and *Spiroplectinata*, from the Aptian and Albian (Senckenberg Naturf. Ges., Abh., 498), have been made by Brunhilde Grabert. These studies are variation statistical investigations, and involve the description of 19 species from 37 populations of about 18,000 individuals. The author demonstrates that there is a gradual transition and splitting off from *Gaudryina* to *Spiroplectinata*.

This year's volume of the "Paläontologische Zeitschrift" has been published in the form of three periodicals. Thanks to great assistance from many sides, it was not necessary to raise the annual subscription rate of DM 15,00 ($4.00). Volume 33 comprises 329 text pages, 35 plates, 67 text figures, and 11 tables.

Amongst the 24 articles, the following relate to micropaleontology:

H. Bartenstein – Biostratigraphy of the Valendis in northwest Germany, based on ostracodes.

H. Beckmann – Marking of foreign microfossils during the process of washing.

F. Berger – Fragments of small vertebrates from the Pleistocene at Hirschbach.

G. Brunner – The Schmiedberg-Abri at Hirschbach Oberpfalz.

A. Eisenack – Chitinous molds of foraminifera from the Silurian and the Jurassic of the Baltic.

S. Geroch – Stratigraphic significance of the arenaceous foraminifera of the Carpathian Flysch.

H. Gocht – Microplankton from the Neocomian of northwest Germany.

J. Hofker – The asterigerinid foraminifera.

G. Lüttig – The ostracodes of the Late Glacial of Tatzmannsdorf (Burgenland).

W. Maync – Remarks on the taxonomy of the Lituolidae.

H. Oertli – *Euryitycythere* and *Parexophathalmocythere*, two new genera of ostracodes from the Lower Cretaceous of Western Europe.

R. Reyment – The description of the foraminiferal genus *Aragonia*.

A. Voges – Conodonts from the Lower Carboniferous I and II (Gattendorfia- and Pericyclus-stage) of the Sauerland.

E. Voigt – The ecologic significance of the hardgrounds in the Upper Cretaceous.

E. Voigt – *Endosacculus molkiae* n. g. n. sp., a presumed fossil Ascothoracide (Entomostr.) as a producer of cysts in the octocoral *Moltkia minuta*.

E. Weiler – Ossiculiths and otoliths from fishes.

It may be of interest to note that 30% of the members of the Paläontologische Gesellschaft are outside Germany.

For the second time since the founding of the European micropaleontologic colloquium we have been honoured to arrange an excursion in Germany. This excursion took place in south Germany, from June 14th to June 22nd. Amongst the 93 participants, were 66 foreign guests, 17 participants came from France and Italy, respectively. Seven came from England and Scandinavia. There were also representatives from the Netherlands, Yugoslavia, Austria, Poland, and Switzerland, and three guests from North Africa. Thanks to the generous assistance of the petroleum industry, the program could be arranged without difficulty. The same applied to the mailing of large quantities of samples. Mainz was the starting point of the excursion. The first few days were devoted to a visit to the Tertiary in the Mainzer Becken. In this classic region of Tertiary paleontology, we were able to visit the most important type localities of the Oligocene and Miocene. The route of the excursion then led us through the Schwäbische Alps, where we observed the whole series of the Mesozoic strata from the Muschelkalk to the Malm. The visit to the marvellous sections of W. Quenstedt and the other great Swabian paleontologists was a great experience for all the participants. The excursion was closed by a visit to the Callovian clay of the Kandern brick works where a

section of about 50 meters is extremely rich in typical ostracodes and foraminifera. We are grateful to the Wintershall, Erdölwerke Niedersachsen, for making this last meeting such a success. We hope that the friendly bond joining all the participants in the preceding five colloquia will become even stronger, thereby emphasizing that true progress in science is based on cooperation.

This year's meeting of the Palaeontologische Gesellschaft took place in Berlin from August 26th to August 29th, 1959. Some of the lectures were held in the Technical University and others in Humboldt University. Amongst the 42 lectures, fifteen were concerned with micropaleontologic problems:

F. Gramann, Hannover – Alterations of the foraminiferal faunas of the Rupel clay in Hessen.

W. Gross, Berlin – The conodont genera *Polygnathus* and *Palmatolepsis*.

J. Helmes, Berlin – The conodont genera *Polygnathus* and *Palmatolepsis* in the Upper Devonian.

H. Jordan, Freiberg – Taxonomy and biostratigraphy of the Lower Devonian ostracodes of the Harz Mountains.

F. Kahler, Klagenfurt – Development of fusulinid research and its future.

K. Klement, Tübingen – Dinoflagellates and hystrichosphaerids from the Upper Jurassic of Southwest Germany.

K. Kraatz, Berlin – Electron microskopic investigations of graptolites.

W. Krutzsch, Berlin – Stratigraphic remarks on the Tertiary flora of the Lausitz and central Germany.

G. F. Lutze, Braunschweig – The genus *Lophocythere* (Jurassic, Ostracoda) as example of the world-wide significance of ostracodes as index fossils.

K. Mädler, Hannover – Microorganisms of the Posidonien Schiefer and their relation to hystrichosphaerids.

A. H. Müller, Freiberg – Fragments of Asteroidea from the Maestrichtian.

K. J. Müller, Berlin – Cambrian conodonts.

F. Schaarschmidt, Berlin – Spores from the Rotliegendes of the Thüringer Wald.

A. Voges, Göttingen – Lack of bilateral symmetry of twin conodont species of the platform type.

W. Ziegler, Krefeld – State of conodont stratigraphy in the Devonian of Europe.

In addition, we had a premiere of the two excellent films of Prof. G. Grell, Tübingen, on morphological development and propagation of living foraminifera.

During the excursions to the different areas in the D.D.R. and the Federal Republic of Germany, participants could collect samples for microzoologic and palynologic tests. The following localities were visited, some of which are type localities: Rügen (Maestrichtian and Quaternary), Misburg (Turonian, Santonian and Campanian), Moorberg (Barrêmian, Aptian and Albian) and Wätzum (Dogger, Wealden, and Valendis) – the three last mentioned localities all in the proximity of Hannover – Haverlahwiese, the important iron mine of Salzgitter (Lias, Dogger, Barrêmian, and Aptian), Göschwitz in Thuringia (Röt and Muschelkalk), Seeberg near Gotha (Rhät and Lias), and Milbitzer rock near Gera Kupferschiefer and Zechstein).

The effort and the skill of the First Secretary of the meetings, Professor W. Simon, and the President of the Paläontologische Gesellschaft, Professor W. Gross, contributed substantially to the harmony and success of the meetings, which fact has been gratefully acknowledged by all participants.

On the occasion of the annual meeting of the Geologische Vereinigung in Mainz, the following lectures concerned with micropaleontologic subjects were held during the first day (14th March):

F. Bettenstaedt – The significance of phylogenetic lines in stratigraphic micropaleontology.

F. Kahler – The value of fusulinids in stratigraphic comparison over great distances.

K. J. Müller – Value and restrictions of conodonts in stratigraphy.

On May 20th and 21st, the geologists of northwest Germany held a meeting in Stade and four micropaleontologic papers on foraminifera, diatoms and pollen were discussed.

J. Jarke – The present distribution of foraminifera in the sediments of the North Sea.

Fr. Grube – The development of the Holstein-Interglacial in the Lower Elbe region.

R. Hallik – The development of vegetation during the Holstein-Interglacial of Hamburg-Hummelsbüttel.

R. Hallik – Sedimentation in the Urstromtal of the river Elbe, especially around Hamburg.

During the general meeting of the Deutsche Geologische Gesellschaft and the Deutsche Quartärvereinigung in Oldenburg, from September 1st to 11th, five lectures related to micropaleontologic problems.

B. P. Hagemann – The stratigraphy of the marine Holocene in the region of the Rhine Estuary.

B. Hallik – Age classifications of the layers of diatomite in the southern Lüneburger Heide.

N. Hayen – Datable horizons in a pollen diagram of the Lengener Moor, their interpretation as to the beginning of peat growth, and the Grenzhorizont.

G. Lüttig – Interglacials at Liebenau on the river Weser, a subdivision of the bottom land silty loam (Auelehm).

W. Selle – The subdivisions of the Riss-Würm Interglacial in northwest Germany and adjacent regions.

At the commemorative meeting on the 90th anniversary of the Hungarian Geological Survey in Budapest, which took place from September 15th–23rd, W. Krutzsch gave a lecture on the state of spore stratigraphy of the Mesozoic in Germany.

At the International Oceanographic Congress in New York, from August 30th to September 12th, W. Schott spoke on planktonic foraminifera from the deep-sea floor of the North Atlantic Ocean, and E. and I. Seibold on examples from the lower Malm of South Germany on foraminifera and the facies of sponge reefs.

Dr. Klaus J. Müller made a lecture tour through England in October and November, visiting the universities in Cambridge, Exeter, Bristol, Swansea, Aberystwyth, Sheffield, Birmingham, Dublin (Trinity College) and London (Kings College). He talked on the use of conodonts in stratigraphic geology. He demonstrated a set of 24 conodont models which had been prepared under his supervision by Mr. C. Herfurth and will be available soon to interested persons and institutions. This tour was organized by Dr. R. H. Ball of the British Museum (Natural History) and the Cultural Counselor of the German Embassy in London.

HEINRICH HILTERMANN
Amt für Bodenforschung
Hannover

MEXICO

CLEMENCIA TÉLLEZ-GIRON

Instituto Politécnico Nacional
Laboratorio de Zoología y Paleontología

Dr. F. Bonet, Head of the Zoology and Paleontology Laboratory of this Institute and his collaborators are continuing active research in micropaleontology. Some of the results of their extensive work have already been published.

Presently studies are being made on the sedimentology and ecology of the coral reefs in Veracruz and Anton Lizardo along with explorations of a similar nature in other coral reefs.

A monograph by the biologist M. Trejo on the genus *Nannoconus* is in press. He was advised and helped in this work by Dr. F. Bonet.

N. Benveniste is continuing her studies on ascidian spicules of Jurassic wells, and on the coccolithophorids of the Tertiary of eastern Mexico.

Petróleos Mexicanos
Laboratorio de Paleontología

In the Paleontological Laboratory of the exploration office of Petróleos Mexicanos special emphasis is now being given to research. M. Robles Ramos, head of the laboratories, is conducting special studies on the subsoil of the Eocene of Mexico and some of the results are already being used for stratigraphic determination in different petroleum regions. These studies are based on planktonic foraminifera. E. K. de Castello, M. T. de Alvarez and J. V. Piñones worked on the microfaunal zonation of the Eocene of the subsoil of the Tampico-Tuxpan embayment.

M. L. Robles Ramos, with the collaboration of C. Flores, completed the zonation of the Eocene of the Iray-Purisima and Sebastián Vizcaíno embayments in Baja California. Y. Eternod has finished his work on the distribution of the foraminifera of the upper middle and lower Eocene of the extreme southwest of the State of Veracruz and in the States of Tabasco, Chiapas and Yucatán. M. L. Robles has completed and has ready for publication her work on the distribution of the basal Paleocene (Danian) in the Paleobay of Tampico-Tuxpan.

In the section of the laboratory under Dr. F. Bonet's direction, the following studies are being carried on: Micropaleontological research on the limestone of Córdoba, Veracruz,

in order to establish a highly advanced zonation plan; A. Becerra is continuing his micropaleontological survey of the Tamabra limestone, in the Poza Rica oil fields; the first results of the research on the paleontology and geology of the peninsula of Yucatán are already published. Other works are being prepared for future publications, amongst which will be a monograph on microfacies of the last mentioned region and other publications on the genus *Clypeina* also from the Yucatán limestones.

In the paleontology laboratory located in Monterey, J. Obregon de la Parra is also doing routine work and special research. A paper is being prepared on the foraminifera of La Peña formation (upper Aptian) in the Sierra of Sabinas-Hidalgo, Nuevo Leon. The study of samples collected from the geological section of the Upper Jurassic in Las Grutas de García, Nuevo Leon, and the samples collected by Engineer J. Carrillo from the Cañon de Perigina, are the objects of special effort on the part of this laboratory.

Universidad Nacional Autónoma de México
Instituto de Geología

Last spring biologist Augustin Ayala, returned from Stanford University after obtaining the master of science degree in geology. He spent 17 months studying micropaleontology.

At present, A. Ayala-Castañares is working, in collaboration with the Scripps Institution of Oceanography of the University of California, on the systematics and ecology of the foraminifera of Laguna de Terminos, Campeche. He is also studying the larger foraminifera of the Upper Cretaceous in the central region of the State of Chiapas, southeast Mexico.

The Facultad de Biología and the Instituto de Investigaciones Científicas of the Universidad de Nuevo Leon have initiated a series of micropaleontological investigations on Mesozoic sediments.

Recent micropaleontological papers which have appeared in Mexican journals are: Ayala-Castañares, A., "Estudio de algunos microfósiles

planctónicos de las calizas del Cretácico Superior de la República de Haití". Paleontología Mexicana, no. 4, 41 pp., 12 pls., 2 text-figs., 1959. – Bonet, F., "Afloramientos del Eocene en le norte de la Península de Yucatán". Asoc. Mexic. Geol. Petr., Bol., vol. 11, no. 1–2, 1958, and "Madreporarios del Terciario del Territorio de Quintana Roo, colectados por J. Butterlin". Asoc. Mexic. Geol. Petr., Bol., vol. 10, no. 9–10, pp. 565–570, 1958. – Butterlin, J., and Bonet, F., "Découverte d'une formation éocéne dans les parties septentrionale et centrale de la presqu'ile du Yucatan (Mexique)". Soc. Géol. France, C. R. Somm., no. 15–16, pp. 389–391, 1958. – Trejo, M. "Dos nuevas especies del género *Nannoconus* (Protozoa). Ciencia, vol. 19, no. 6–7, pp. 130–132, text-figs. 1–2, 1959.

There are two papers in press; the first by Eternod, Y., "Foraminíferos del Cretácico Superior de la cuenca de Tampico-Tuxpan, México" [MS], and the second by Thalmann, H. E., and Ayala-Castañares, A., "Evidencias micropaleontológicas sobre la edad Cretácico Superior de las "Pizarras – Necoxtla" Paleontología Mexicana, no. 5 [MS].

Clemencia Téllez-Girón
Laboratorio de Paleontología
Petróleos Mexicanos
Mexico 1, D. F.

POLAND

KRYSTYNA POŻARYSKA

There are two trends in paleontology and micropaleontology in Po-

land, one biological, the other biostratigraphic. Biological work is being done by the well-known paleontologist, Professor Roman Kozłowski, with his students, at the Paleontological Institute of the University in Warsaw and at the Polish Academy of Sciences. Biostratigraphic studies are being made at other university centers and at various industrial institutes. Biostratigraphic studies, as applied to geology, are being carried on by Professor F. Bieda and his collaborators in Cracow, by the micropaleontological laboratories of the Geological Survey at Warsaw and Cracow, and by the research institutes of the petroleum industry in Cracow and Piła.

Twenty-one scientists and eight technicians are collaborating, under the leadership, of Professor Kozłowski, at the Paleontological Institute in Warsaw. This Institute has a branch in Poznań, managed by Professor M. Różkowska, where six scientists and two technicians are employed. Many groups are being studied in these laboratories, including ostracodes, foraminifera, scolecodonts, conodonts, and such micro plankton as Coccolithophoridae, Hystrichosphaeridae, and Peridinieae. In each study, stress is placed not only on taxonomy and stratigraphy but above all on studies of ontogeny, phylogeny, intraspecific variability, and the evolution of species through geologic time. At this center, stratigraphy is regarded merely as an aid in obtaining data on particular species as biological units. Thus, the study of a species is generally carried out on a great number of individuals in order to be able to treat species as populations. Among the main technical achievements of this Institute are the development of methods of dissolving rocks on a large scale by chemical treatment in acids, and the application of biological methods such as the use of a microtome in sectioning organisms with chitinous skeletons. Hydrofluoric, acetic, and hydrochloric acids are used for dissolving large amounts of Paleozoic erratic boulders, as well as for other rocks found *in situ* in Poland. Thus, after

many years, a large amount of material has been prepared from bone beds of different ages. This material includes very well-preserved, non-compressed graptolites, rhabdopleurids, bryozoans, scolecodonts, conodonts, hydrozoans, radiolaria, Paleozoic foraminifera, hystrichosphaerids and algae, as well as a great number of *incertae sedis*. The material obtained by the dissolving of rocks is neither deformed nor damaged by this acid preparation, and is thus very suitable for anatomical study.

There are three laboratories at the Paleontological Institute in Warsaw. The Paleozoological Laboratory is under the direction of Professor R. Kosłowski, the Micropaleontological Laboratory is headed by Professor W. Pożaryski, and the Paleobotanical Laboratory is directed by Professor M. Kostyniuk. Micropaleontologic investigations on Paleozoic foraminifera are being made by S. Duszńska; work is being done by Dr. K. Pożaryska on the Upper Cretaceous and Paleocene foraminifera, H. Wolanska is studying the Oligocene foraminifera, and I. Brodniewicz is working on the Pleistocene and Recent foraminifera. J. Blaszyk is studying the Middle Jurassic ostracodes, and F. Adamczak the Middle Devonian ostracodes. H. Gorka is carrying out a program of study of coccolithophorids, hystrichosphaerids, and dinoflagellates of Cretaceous age.

Professor F. Bieda, one of the most eminent specialists in the study of nummulites, is doing work in biostratigraphy. This work is being done, with the aid of many collaborators, at the Paleontological Institute of the Academy of Mines in Cracow. Professor Bieda's numerous works on the nummulites have yielded biostratigraphic data for the detailed stratigraphy of the Polish Carpathian Flysch deposits. In addition to work on the larger and smaller foraminifera from the Carpathian Eocene (Prof. F. Bieda and T. Smigielska), work on Miocene foraminifera (E. Luczowska), Carboniferous foraminifera (Dr. S. Liszka), and Carpathian Eocene

Bryozoa (Dr. J. Małecki) is also being done.

The stratigraphy of the Carpathian Flysch, based on the foraminifera, is under study by Professor M. Książkiewicz and Dr. S. Geroch at the Geological Institute of Jagiellonian University, in Cracow. It should be noted that all these studies are, in some way, continuations of Professor Grzybowski's pioneer work, initiated in Poland at the end of the 19th century.

The research work of the micropaleontological laboratories of the Polish Geological Survey and the Research Institute of the Petroleum Industry are, to a great degree, in the field of applied geology. At the Micropaleontological Laboratory of the Geological Survey, under the guidance of Prof. W. Pożaryski, work is being done on detailed correlation of outcrops and of wells and borings that are currently being drilled. In addition, the study of foraminifera and ostracodes from different stratigraphic units is being carried on to establish a standard section for different regions. At the beginning of this work, special boreholes were drilled in places where the desired rock sequences were fully developed (so-called basic boreholes). These detailed studies of stratigraphic sections are the most important accomplishments of this Laboratory where six scientists and eight technicians are employed. The examination of foraminifera and ostracodes is being done by O. Styk (Triassic), J. Kopik and Dr. W. Bielecka (Jurassic), Dr. J. Sztejn (Lower Cretaceous), and by E. Witwick and E. Gawor-Bieda (Upper Cretaceous). As there is only a meager Tertiary marine section in the Polish Lowland, it was decided to work on Mesozoic strata only.

The Micropaleontological Laboratory of the Geological Survey in Cracow, which is staffed by six scientists, is also engaged in the examination of Carpathian Flysch foraminifera. Under the guidance of J. Liszka, the foraminiferal assemblages of the following stratigraphic units are being investigated by

J. Blaicher (Magura unit), J. Morgiel (Inoceramian unit), J. Liszka (Subsilesian unit), S. Aleksandrowicz and W. Szottowa (Miocene of the Carpathian foreland), and S. Aleksandrowicz (Miocene of the Upper Silesian Basin).

The Central Laboratory of the Petroleum Industry in Cracow is investigating the foraminifera of the nearby Carpathian region. It is also carrying on various research drilling investigations throughout Poland. The following problems are being investigated there from the stratigraphic viewpoint: Miocene foraminifera (Dr. Z. Kirchner, Head); Cretaceous foraminifera (F. Huss); Jurassic foraminifera (A. Jednorowska, K. Morawska, and J. Waśniowska); Paleozoic foraminifera (Z. Milewska); and Cretaceous foraminifera from the Lowland of Poland (I. Heller).

The Pila branch of this laboratory is doing work on the Mesozoic foraminifera of northwestern Poland (A. Pieniazek and A. and D. Didziak).

Aside from the paleobotanical laboratories, more than thirty-five scientists are currently employed in Polish micropaleontological laboratories.

Palynologic research in Poland is also being done at various university institutions. One center is at the Botanical Institute of the Jagiellonian University and the Polish Academy of Sciences in Cracow, and the other at the Geological Survey in Warsaw.

In the Palynological Laboratory of the Botanical Institute in Cracow eleven scientists, under the guidance of the well-known Polish botanist, Professor W. Szafer, are presently engaged in problems relating to Tertiary and Quaternary palynologic stratigraphy. Much attention is being given to the problem of the Pliocene-Pleistocene boundary. The following problems are being investigated: Late glacial and Holocene floral histories of various regions of Poland; glacial and interstadial floral periods; interglacial floral

periods; the Miocene flora of Poland; and variability of pollen in such genera as *Pinus*, *Picea*, and *Abies*.

The Laboratory of the Geological Survey in Warsaw, under the direction of Dr. J. Bobrowska, with seven scientists and two technicians, is the second largest center of palynologic research in Poland. Up to this time, the work has been limited to paleobotanical investigation of the brown Tertiary coals of the Polish Lowland. Recently, however, the scope of the work has been enlarged to include all Mesozoic and Upper Permian strata as well, thus involving the whole of the Mesofiticum flora. The principal emphasis is still placed on the study of micro- and megaspores from continental beds of Lower Cretaceous (Wealdian) and Liassic age, which yielded the fundamental data for determination of the stratigraphic succession. In addition, palynological study of the Miocene beds of the nearby Carpathian region, and from the Quaternary, are still in progress.

Extensive studies of Carboniferous micro- and megaspores are being carried on by Dr. S. Dybova and Dr. A. Jachowicz.

At the Paleobotanical Laboratory of the University of Warsaw, one scientist is initiating a study of the Carboniferous spores of eastern Poland. About twelve persons are employed in various other scientific institutions in palynological study, primarily on the Pleistocene and Holocene deposits of Poland.

KRYSTYNA POŻARYSKA
Paleontological Institute
Warsaw, Poland

SCANDINAVIA

This report covers micropaleontological activities for the years 1958–1959. The previous report was published in 1958, vol. 4, no. 2.

FORAMINIFERA

Studies in the microfauna of deposits along the Cretaceous—Tertiary boundary are being carried out at the University of Stockholm. W. Berggren is working with planktonic foraminifera and R. Reyment with benthonics. Berggren recently published a paper entitled "Some planktonic foraminifera from the lower Eocene (Ypresian) of Denmark and northwestern Germany" (Stockholm Univ., Contr. Geol., vol. 5, no. 3, pp. 41–108, 13 plates, 1960).

A statistical analysis showing the intrapopulation variation within a particular species of this fauna has been made by Berggren and B. Kurtén and will be published in early 1960. Berggren will present two papers on Maestrichtian and type Danian planktonic foraminifera at the International Geological Congress in Copenhagen in 1960.

Planktonic foraminifera can, *a priori*, be reckoned with as suitable markers in intercontinental correlations. Several investigations made in recent years seem also to indicate that this is true. The Russian paleontologist, Dr. N. N. Subbotina seems to have been the first (1936) to have used planktonic foraminifera in connection with stratigraphy in her zonation of Paleogene deposits of the northern Caucasus mountains. She and other Russian paleontologists subsequently have made several other similar investigations. Corresponding studies in the western hemisphere were made during the fifties, especially by Bronnimann, Bolli, and Loeblich and Tappan. The planktonic foraminifera of the type Danian of Denmark have been studied by Troelsen and Bronnimann. In a very recent paper on Danian sea urchin spines (see below) F. Brotzen claims that Upper Cretaceous – Paleogene globigerinids were benthonic.

Berggren has concentrated his work in Denmark and surrounding areas (northwest Germany, and Skåne, in Sweden), and he has also direct personal knowledge of American and Russian material. He has found that greater refinement is needed in the existing nomenclature and taxonomy of planktonic foraminifera in order to achieve greater accuracy in stratigraphic correlation. The present unsatisfactory state with regard to part of the planktonic foraminifera is due to several circumstances. These include inadequate descriptions and poor illustrations, lack of knowledge of foreign languages, lack of communication between paleontologists in various countries, neglect of direct comparative studies of material, and great discrepancies in the concept of the range of specific variation. Berggren feels that a statistical analysis of variation would diminish this discrepancy and he states that for the aforementioned reasons many species from time-equivalent deposits in various parts of the world are masquerading in the literature under various names. Berggren's main material comes from a Tertiary Danish plastic clay which contains exceptionally well-preserved planktonic foraminifera. This clay had been interpreted earlier as being of middle Paleocene to middle Eocene age, but is now shown to belong to the lower Eocene (Ypresian). Direct study of type materal was made whenever possible in comparisons with foreign material. It was tentatively established that the plastic

clay and the lower Eocene 3 facies of northwest Germany correlate well with the lower Eocene of the Gulf Coast area (Nanafalia, Tuscahoma, and Hatchetigbee formations), as well as with the lower Eocene marls in the Caucasus and similar sequences elsewhere in the Soviet Union.

Reyment has so far published two papers on benthonic foraminifera from the Upper Cretaceous—Paleogene, namely "Zur Fassung der Foraminiferengattung *Aragonia*" (Paläont. Zeitschr., vol. 33 nos 1–2, pp. 108–112, 1959) and "The foraminiferal genera *Afrobolivina* gen. nov. and *Bolivina* in the Upper Cretaceous and Lower Tertiary" (Stockholm Univ., Contr. Geol., vol. 3, no. 1, pp. 1–57, 7 plates, 1959). The first paper is a note on the taxonomic position of the agglutinated genus *Aragonia* (uppermost Cretaceous—Eocene). It was shown, by use of thin sections, that the genus lacks a toothplate and porous walls and therefore is not related to *Bolivina-Bolivinoides*, as previously surmised.

In the second paper, it was demonstrated that *Bolivinoides* is a junior synonym of *Bolivina*. Bolivinoid forms with a toothplate, porous walls and a tendency to become uniserial in the adult part of the test and with a terminal aperture are referred to the subgenus *Loxostomoides* Reiss of *Bolivina*. *Loxostomum* Ehrenberg, on the other hand, which lacks a toothplate and pores in the wall of the test, cannot be grouped with the Bolivininae. A new genus *Afrobolivina* was erected, characterized by large bolivinoid tests with overlapping chambers, ribs, and plications ornamenting the surface. A toothplate is present and the chambers are globular and are provided with several septa around the contact of chamber walls with the test wall.

Reyment claims that the bolivinids are good stratigraphic markers in the uppermost Cretaceous and the Lower Tertiary. For Nigeria and the Cameroons the following time sequence of genera was found: Upper Maestrichtian—basal Paleocene:

Afrobolivina; Paleocene: *Loxostomoides* (elsewhere beginning in the Upper Cretaceous). Eocene—lower Oligocene: *Bolivina* (*Bolivina*) (elsewhere beginning in the Jurassic).

A critical study of some species of *Nonion* was published by A. Nørvang in Medd. Dansk Geol. Forening, vol. 14, no. 2, pp. 141–150, 1959. He states that the diagnoses of *N. halkyardi* Cushman and Thomas, *N. affine* (Reuss), *N. soldanii* d'Orbigny, and *N. barleeanum* (Williamson) are in reality identical. This is also verified by his examination of the material at hand. He failed to find suitable distinct characters to distinguish well-defined species in this group. The present classification seems artificial to the author who accordingly states that it is of no stratigraphic importance.

Eisenack reported on chitinous globules from the island of Gotland (Silurian) which he interprets as early foraminifera (Paläont. Zeitschrift, vol. 33: nos. 1–2, pp. 90–95, 1959). A new genus was erected (*Archaeochitosa*) and is represented by three new species, two from Gotland and one Jurassic from an East Prussian Geschiebe specimen. Attention was called to minute spherules of unknown origin within the globules.

CHITINOZOA

Eisenack has published a paper on chitinozoa and other microfossils, "Microfossilien aus dem Ordovizium des Baltikums" (Senckenbergiana Lethaea, vol. 59:516, p. 389–405, 2 plates, 1958). Microfossils in Tremadoc and Arenig deposits in Estonia are listed. Chitinozoan species are less numerous than chitinous bodies referred to as hystricospheres. He erected a new genus of chitinozoa, *Lunulidia* from the *Dictyonema* shale.

OSTRACODA

The study of ostracodes at Uppsala University is concerned with Ordovician and Silurian faunas. Stratigraphic work in connection with a drilling program is carried out largely with the aid of ostracodes.

V. Jaanusson is publishing an extensive paper on the Middle Ordovician (Viruan) of the island of Öland, based on surface and subsurface material. The Lower and Middle Ordovician of a core from Gotska Sandön in the central Baltic is being treated by Jaanusson and the Upper Ordovician by A. Martinsson.

Martinsson is publishing a study on the Ordovician primitiopsids of Oklahoma, including a review of the nine rather different Ordovician, Silurian, and Devonian genera referred to Primitiopsidae. He is also continuing his studies on the paleocopid ostracodes from the Silurian of Gotland, especially the families Beyrichiidae, Primitiopsidae and Hollinidae. These ostracodes, which are mainly derived from marl facies, and acid resistant microfossils from limestone facies will furnish the material for a future micropaleontologic study on the stratigraphy of the Silurian of Gotland.

In Stockholm, Ordovician and Upper Cretaceous—Paleogene ostracodes are also being studied. Three papers on the latter group have been published, namely: R. A. Reyment, Die Ostracodengattung *Paijenborchellina* im Unter-Eozän Nigeriens (Stockholm Univ., Contr. Geol., vol. 3, no. 7, pp. 139–143, 2 plates, 1959). R. A. and E. Reyment, *Bairdia ilaroensis* sp. nov. aus dem Paleozän Nigeriens und dis Gültigkeit der Gattung *Bairdoppilata* (Ibid., vol. 3, no. 2, pp. 59–68, 1 plate, 1959). R. A. Reyment and O. Elofson, Zur Kenntnis der Ostracodengattung *Buntonia* (ibid., vol. 3, no. 9, pp. 157–164, 3 plates, 1959).

In the first paper attention is called to the occurrence of the rare genus *Paijenborchellina* in the lower Eocene of West Africa. It was known earlier only from the Barremian of Azerbaijan, the Caucasus and the Caspian Sea areas. Because of the well-preserved marginal structures, the genus is referred to the subfamily Cytherurinae. In the second paper, it was shown that the genus *Bairdoppilata* Coryell, Sample, and Fields 1935 is synonymous with

Bairdia. The anterior and posterior selvage teeth which are supposed to distinguish *Bairdoppilata* from *Bairdia* may occur in the range of variation of a single *Bairdia* species. The new species which was closely studied and described in the paper is from the Paleocene of West Africa. The third paper is a revision of the genus *Buntonia* Howe 1935 which is shown to be the senior synonym of *Semicythereis* Elofson 1943, a Recent genus; and *Protobuntonia* Grekoff is a subgenus of *Buntonia*. The identification of a fossil genus with a modern one was demonstrated in this case by the cooperation of a paleontologist (Reyment) and a zoologist, viz., the recognized specialist on modern ostracodes, Dr. O. Elofson. There may still be several unknown cases of similar synonymy due to the fact that fossil forms are characterized by their shells, whereas the Recent species are identified mainly by their extremities.

CONODONTS

M. Lindström has continued his conodont studies and published a paper on "Conodonts from the Crug limestone (Ordovician, Wales)" (Micropaleontology, vol. 5, no. 4, pp. 427–452, 4 plates, 1959). S. Bergström has a paper ready for press on conodonts from the Ludibundus limestone (Middle Ordovician) of the Tvären area (southeast Sweden).

Lindström discussed at some length the question as to whether an artificial or a natural classification of conodonts should be used. He is definitely in favour of an artificial classification and warns against nomenclatorial and taxonomic decisions at an early stage of the work on little known groups such as the conodonts. We have no definite knowledge of the conodont animal and it may be impossible to distinguish between homeomorphy and true affinity. Six new species were established in his paper. Stratigraphic remarks were made on the Keisley limestone, which is supposed to be Caradocian, in part, because of the presence of some conodonts which also occur in the Caradoc Crug limestone of Wales.

ECHINOID SPINES

F. Brotzen has examined the zonal occurrence of echinoid spines in the type Danian region and has recently published the results of these studies in a paper entitled "On *Tylocidaris* species (Echinoidea) and the stratigraphy of the Danian of Sweden" (Sveriges Geol. Unders., ser. C, no. 571, p. 1–54, 2 plates, 1959). This paper includes a bibliography of no less than 875 publications on the world-wide occurrence of the Danian and Paleocene. It is certainly the most complete such list in existence.

Echinoid spines of the type Danian region have been studied over a long period of time. Brünnich Nielsen suggested in 1909 that they might be useful in stratigraphic correlations. Brünnich Nielsen, Ödum, Ravn, and Wind have subsequently studied such spines and employed them in the stratigraphic division of the Danian. Brotzen revised the spines and added several observations on their geological occurrence, basing his statements to a great extent on examinations of the extensive exposures in the big quarry at Limhamn in Skåne.

The spines are referred to the genus *Tylocidaris* and Brotzen classifies the different forms as species (form-species or organ-species) using binominal nomenclature. The species exhibit a wide variation; small specimens are not identifiable. Three new species are described, viz. *T. rosencrantzi*, *T. windi*, and *T. ravni*. On the basis of species of sea urchin spines, Brotzen divides the Danian of the type region into four zones, viz.:

Upper Danian– *T. herupensis* zone

Middle Danian–$\begin{cases} T.\ bruennichi & \text{''} \\ T.\ rosencrantzi & \text{''} \end{cases}$

Lower Danian– *T. oedumi* ''

CHAROPHYTES

Recent and fossil charophyte fructifications have been studied extensively over a long period of time

by H. Horn af Rantzien. In 1959 he published three papers, namely, "Recent charophyte fructifications and their relations to fossil charophyte gyrogonites" (Ark. Botanik, K. Svenska Vet.-Akad., ser. 2, vol. 4, no. 7, pp. 165–332, 27 plates, 1959). "Morphological types and organ-genera of Tertiary charophyte fructifications" (Stockholm Contr. Geol., vol. 4, no. 2, pp. 45–197, 21 plates, 1959), and "Comparative studies of some modern, Cenozoic, and Mesozoic charophyte fructifications" (ibid., vol. 5, no. 1, 1959). The last paper constitutes his formal doctoral thesis which was defended on Nov. 21, 1959. Dr. L. Grambast, of Sorbonne University, Paris, acted as the faculty opponent.

Horn's studies are based on vast material, both Recent and fossil, from various parts of the world. In his work on modern forms he investigated 23 species representing all of the seven Recent genera. These studies were made with the purpose of forming a basis for the evaluation of fossil forms. The oosporangial membrane and the structures developed from it were studied in thin sections. With regard to the calcareous shell, emphasis was laid on the apical structure and, secondly, the basal area with the plug filling the basal pore. The descriptions of both the exterior of the shells and the thin sections are very detailed and careful and the illustrations are elucidative and clear.

The systematic study of Tertiary charophyte fructifications was based on these morphological-anatomical characters and is purposely artificial. Natural classification was not considered appropriate, as only the fructifications were treated. These were classified as organ-species and organ-genera, which constitute groups of higher rank called types. These artificial units may, to a certain extent, be natural taxa. The author recognized seven types and 15 organ-genera, nine of which were established before; two were emended, and six are new. Dr. Grambast is of the opinion that four of them are justified and useful but considers two of them—*Grambastichara* and

Charites—to fall within the range of *Chara*, in a natural system.

Horn af Rantzien's extremely careful investigations and a few similar recent studies by other workers indicates that fossil charophyte fructifications are potentially good stratigraphic markers. It now seems appropriate to start using them in stratigraphic correlations and to abolish the viewpoint that they are of little use in that respect.

DIATOMS

The Soviet literature on diatoms is abundant but apparently poorly known in Western countries. This is mainly due to meagre professional contacts, difficulties in obtaining pertinent publications, and linguistic trouble. Dr. R. W. Kolbe (Stockholm) and Dr. A. I. Proschkina-Lavrenko (Leningrad) have recently published a joint annotated list of literature on diatoms issued in the Soviet Union during the period 1918–1957 (Stockholm Univ., Contr. Geol., vol. 4, no. 1, 1959), which should be of great help to diatomologists. This list includes 310 publications on both modern and fossil diatom assemblages, which are reviewed. Purely floristic lists of species were not included but reference is made to Russian bibliographies covering such publications. The annotated list can be obtained from the distributor (Almqvist and Wiksell, Inc., Gamla Brogat., 26, Stockholm, Sweden) The price is $2.30.

POLLEN AND SPORES

The Palynological Laboratory of the Swedish Natural Science Research Council was considerably enlarged in 1958. Because of this expansion, it moved to new quarters in Nybodagatan 5, Stockholm-Solna. The collections ot the laboratory now comprise about 25,000 pollen and spore slides. Among these is a special collection of pollen slides of Scandinavian plants. These include about 1000 species, duplicates of which have been distributed to six other institutions in Sweden and three in Finland. Besides this "sporotheka"

(i.e. collection of pollen and spores slides), a "tomotheka" (collection of slides, with thin to ultrathin sections through pollen grains and spores) is now being established. The studies at the laboratory have been concentrated mainly on advanced microscopy and its use in palynology. Special attention has been paid to pollen morphology in the Acanthaceae and Compositae.

Late in 1957, a clay sample from a water well drilled in Skåne, southern Sweden, was sent for analysis to the Department of Quaternary Geology at the University of Lund. It had been taken from an unidentified deposit beneath Pleistocene layers. The department is well equipped for pollen and spore analyses. Dr. T. Nilsson who is in change, took a personal interest in the problem. He immediately found that the sediment was very interesting, being extremely rich in plant microfossils. Nilsson presented his results in a paper called "Über das Vorkommen eines mesozoischen Sapropelgesteins in Schonen" (Lund Univ., Årsskrift, N. F. Avd. 2. vol. 54, no. 10, pp. 1–111, 8 plates, 1958).

The deposit apparently is at least 60 meters thick and consists of sand, clays, brown shale, and conglomerates. The main interest centered around the brown shale (approximately 25 meters thick) which yielded the majority of the plant microfossils. This shale, like other parts of the stratigraphic sequence was examined by X-ray and TD-analyses. Fischer analyses indicated an oil content of 5.75–10.5% in the brown shale; the hydrogen/carbon ratio was 11.3–14.1. Algae of *Botryococcus* type are very abundant and the shale could be classified as an oil shale or sapropel shale. It contains much siderite and pyrite. The brown shale was evidently deposited in a stagnant limnic environment. Similar rocks of corresponding age have not been observed previously in Skåne, Denmark and in Germany. For the age determination of these layers, which yielded very few megafossils, Nilsson compared his plant microfossils with those from other

dated classical deposits in Skåne, with known megafossils. He concluded that the brown shale is uppermost Rhaetic in age; the sequence of strata extends from lower Rhaetic to basal Liassic.

Nilsson's classification of the sporomorphs is artificial or morphographic according to Potonié. He also gave references to natural systematics, if sufficient evidence existed for such identifications. He referred his form units (species and genera) to the following 6 groups: 1. trilete, 2. monolete, 3. monocolpate, and 4. tricolpate sporomorphs; 5. sporomorphs without germinating fissures of dehiscence ridges, and 6. sporomorphs with air sacs. Sixty-four species were reported, 50 of them being new. They were referred to 35 form-genera, 12 of them being new. These are: *Auritulinasporites, Cosmosporites, Trachysporites, Cyclinasporites, Bracteolinasporites, Chasmatosporites, Limbosporites, Cerebropollenites, Crassipollenites, Lobosporites, Schismatosporites, Taedaepollenites.*

Spores of the form-genus *Chasmatosporites* are predominant. They are interpreted as the microspores of *Lycostrobus scottii* Nathorst.

Dr. Britta Lundblad has studied plant fossils of the Rhaeto-Lias of Skåne (southern Sweden) for some time and has published several articles on its mega- and microfossils. She emphasizes that cuticular analyses and megaspores are useful stratigraphic indicators. With regard to cuticular analyses, she states the remarkable fact that stratigraphic correlations based on such studies have not yet received much attention in countries with good possibilities for such work. In the United States, for instance, this line of study has been ignored almost entirely. Leaf-cuticles of gymnosperms were reviewed in a paper by her in 1959 (Stockholm Univ., Contr. Geol., vol. 3, no. 4, p. 83–102). It emphasized their usefulness as stratigraphic markers, especially in Triassic-Jurassic stratigraphy (Rhaeto-Liassic floras and their bearing on the stratigraphy of Triassic-Jurassic rocks). The epidermal characters of

Ginkgoales were described in detail in another recent paper (K. Svenska Vet.-Akad. Handl., Ser. 4, vol. 6, no. 2, pp. 1–38, 6 plates, 1959).

Certain lycopsid megaspores are very useful for correlations in the Rhaeto-Liassic. Dr. Lundblad has especially studied three such organ-species, viz. *Lycostrobus scottii*, *Triletes pingui*, and *Riccisporites tuberculatus*. The first of these has proved to be a reliable indicator of lower Liassic strata of east Greenland, Germany and Sweden (*Thaumatopteris* as-semblage-zone), although there apparently is some overlap into the uppermost Rhaetic (*Lepidopteris ottonis* zone). *Riccisporites* is a charac-teristic contemporaneous fossil as demonstrated in another of her recent papers (Grana Palynologica, vol. 2, no. 1, pp. 1–10, 1 plate, 1959), but the smooth *Triletes* species must be used with discrimination in stratigraphic work.

J. Sen re-examined some Devonian megaspores, mainly from coal seams from the Arctic Bear Island (Geol. Fören. Stockholm Förhandl., vol. 80, no. 2, pp. 141–148, 1958). They were once (1902) described by Nathorst who did not propose any names. Sen referred all of them to *Triletes*. Two species are new (probab-ly also a third) and the fourth was identified as *T. nammillarius* Bart-lett (?), which is common in the Pennsylvanian.

IVAR HESSLAND
Geologiska Institutet
Kungstensgatan 45
Stockholm 6